ETOILE DU NORD

Ack
24/1/89

Minneapolis, Minn. Dec. 4 — 1888

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~~ 2d 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.

Julius Bien lith. N.Y.

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
N. H. WINCHELL, STATE GEOLOGIST.

1882–1885.

THE

GEOLOGY OF MINNESOTA.

VOL. II, OF THE FINAL REPORT.

BY N. H. WINCHELL,
ASSISTED BY WARREN UPHAM.

SUBMITTED TO BE PRINTED AUGUST 20, 1885, AND PUBLISHED UNDER THE DIRECTION OF HON. FRED VON BAUMBACH, SECRETARY OF STATE (1885), AND THE SPECIAL COMMISSION CREATED BY LAW TO SUPERVISE THE PUBLICATION OF THE FINAL REPORTS OF THE SURVEY, CONSISTING OF THE GOVERNOR, THE SECRETARY OF STATE AND THE STATE GEOLOGIST.
(1885–1888.)

ILLUSTRATED BY FORTY-TWO PLATES,
AND THIRTY-TWO FIGURES.

ST. PAUL, MINN.:
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1888.

TABLE OF CONTENTS.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXIV.

CHAPTER XXIX.

CHAPTER XXX.

LIST OF PLATES AND THEIR ORDER.

BOARD OF REGENTS.

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LETTER OF N. H. WINCHELL, STATE GEOLOGIST.

THE UNIVERSITY OF MINNESOTA.
August 20, 1885.

Cyrus Northrop, President of the University,

DEAR SIR: I have the pleasure to transmit for publication the manuscript which is intended to constitute Volume II of the final report on the *geological and natural history survey* of the state. According to the geographic order which has been followed this volume describes, in the same manner as in the first volume, and illustrates with suitable maps and other figures, the superficial geology of the central counties of the state, thirty-nine in all, embracing a total area of 28,279 square miles.

With great respect,
Your obedient servant,
N. H. WINCHELL,
State Geologist.

LETTER OF PRESIDENT CYRUS NORTHROP.

THE UNIVERSITY OF MINNESOTA, MINNEAPOLIS,
August 20, 1885.

Professor N. H. Winchell, State Geologist,

DEAR SIR: I have the honor to acknowledge the receipt of your letter of the 20th instant, transmitting the manuscript of the second volume of your final report. It gives me pleasure to see a work of such vast importance to this commonwealth going steadily on toward completion. The interest in the first volume manifested by the people of the state and by scientists throughout the world bespeaks a warm reception for its successor.

Respectfully yours,
CYRUS NORTHROP,
President.

PREFACE.

This volume is devoted entirely to the description of the county geology of the central portion of the state, and its colored plates embrace about one third of its total area. Necessarily the phenomena of *the drift*, with which this portion of the state is heavily covered, have occupied a large share of attention and space. These features have been studied assiduously by Mr. Upham, and the descriptions are written principally by him. The thoroughness and perseverance with which he has gathered these facts and grouped them into systematic relationships are worthy of high commendation, and the discussions in which he indulges in explanation of them will be received by geologists, and especially by the citizens of the counties described, with satisfaction and pleasure. The great drama of the *second glacial epoch*, at least the closing acts of it—the retreat of the margin of the ice sheet across Minnesota—is the theme of the principal part of this volume. The commencement of this history is given in the first volume, and it is not yet closed with the conclusion of this. It will share largely in the contents of another volume.

The halting-periods and places, in this retreat, the formation of marginal moraines, the stopping up of drainage courses so as to cause temporary and shifting lakes of fresh water, the terracing of southward-flowing streams, the spreading of lacustrine clays, the shrinkage of watercourses to their modern sizes—these records, and the length of time involved therein, constitute the principal topics of these chapters.

The geology of some of the eastern counties embraces some account of the indurated rocks, extending from the crystalline rocks to the Trenton. But, with the exception of the alternating sandstones and magnesian limestones that preceded the Trenton age, these formations do not afford facts enough in the scope of this volume to warrant any broad generalizations as to their genetic relations and general geology. They must be considered in the light of comparative studies on the rocks in other parts of the state and in Wisconsin, and they will be found further treated of in some later volume of the final report.

In the ascent of the Minnesota valley for the purpose of geological examinations, in 1873, two different formations of limestone were met with, separated by a white sandstone. These were designated, from the towns at which their characteristic outcrops occurred, the Shakopee limestone, the St. Lawrence limestone, and the Jordan sandstone. The thickness of neither one of these was known accurately, but the Shakopee limestone was said to be "about seventy feet," the Jordan sandstone "about seventy feet," and of the St. Lawrence limestone not more than fifteen feet could be affirmed.

In subsequent years, as the survey progressed southeastwardly through Fillmore, Houston and Winona counties, these three parts were distinctly recognized, and this three-fold division was described at Lanesboro, Troy, Lewiston (near Stockton), and in western Wabasha county. In ascending the Mississippi valley in the progress of the survey, the intervening sandstone, as recognized in the southeastern part of the state, and the Shakopee limestone, gradually lose the development which they were seen to have in the southeastern part of the state, and the "Lower Magnesian," as defined by Dr. Owen, seems to become one great limestone stratum by the union of the two limestones through the omission of the intervening sandstone. This omission, however, is not found to prevail everywhere even in the more northern counties, since in Goodhue and Washington counties this sand-rock is plainly preserved, and has an observed thickness of five to ten feet, occurring in lenticular strata.

Again, about in the same proportion and rate of progress, as the sandstone separating the two limestones shrinks in thickness, another limestone is developed in the Mississippi bluffs at a considerably lower horizon, increasing toward the north and northwest. This change has been the cause of some mistaken identifications of stratigraphy by the survey, both in the Mississippi valley and in the Minnesota valley, which are corrected in this volume. For the purpose of adjusting some of the apparent discrepancies the writer recently made a cursory re-examination of those points in the Minnesota valley which were likely to throw light on the problem. The stratigraphic facts brought out by this re-examination are expressed below. Prior to this Mr. Upham had called attention to the great apparent thickness of the Shakopee limestone as developed by deep wells at Shakopee, which would make it parallelize with the chief limestone formation in the bluffs of the Mississippi at Hastings, instead of with the upper member which had been traced, under the name of Shakopee limestone, from Houston county to Hastings, and had shown by a study of the deep wells of the central part of the state that a calcareous member, comparable to the St. Lawrence limestone at St. Lawrence, exists below that which had been regarded its equivalent in the Mississippi bluffs.

With the facts all in mind, it was deemed best to make a special search, in the Minnesota valley, for the thin upper sandstone which had been found gradually thinning out toward the north, and that overlying upper limestone which had been identified since 1873, as the Shakopee limestone in the valley of the Mississippi, and to ascertain their actual relations to the Shakopee at Shakopee, and to the St. Lawrence at St. Lawrence. It is evident, whatever might be the result, that the extension of the strata there seen, and those only, would constitute the Shakopee and St. Lawrence limestones in their development further southeast and east.

On making a re-examination of the quarries in the limestone at St. Lawrence it became evident at once that this limestone represents the westward extension of that quarried at Lake City and Hokah, and hence that it had been a mistake, in Volume I of this report, to designate the chief limestone of the Mississippi bluffs "St. Lawrence." This is evident not only from its lithology but also from its thickness, and from facts which were observed afterward at points higher in the Minnesota valley. This being established, it is evident that the sandstone which directly overlies it (the Jordan) must be in the Mississippi bluffs the upper portion of the St. Croix, having a thickness of nearly a hundred feet.

Having thus determined the equivalents of the St. Lawrence and the Jordan, in the Mississippi valley, it also became evident that the regular order would require that the principal limestone in one place should parallelize with that of the other, and that hence the great limestone, as supposed to exist at Shakopee, could be no other than the great stratum seen at Hastings.

The existence of the great thickness of this limestone at Shakopee rests on the uncertain testimony of the deep wells there which have penetrated it. But although the details of these wells are not obtainable so as to show in all cases the existence in this limestone of thin beds of sandrock, yet they unite with sufficient testimony to demonstrate that there is under Shakopee village, extending far below any rock exposed in the quarries, a stratum of limestone, or what the well-drillers denominate wholly limestone, that is entirely comparable to that in the bluffs at and near Hastings, and should be parallelized with it. This thin sandstone is mentioned in the record of J. A. Wilder's well, on the high prairie near Shakopee, given by Mr. Upham on page 125. The quarries at Shakopee involve only from 15 to 20 feet of the uppermost layers of this stratum, and to these layers the term *Shakopee* should be applied—and only to these, or, at most, to those underlying layers that extend downward to the thin sandstone which is known to exist, with more or less persistence, in this great formation, about 25 feet below its top (see reports on Fillmore, Houston, Winona, Wabasha, Olmsted, Goodhue, Dakota and Washington counties) and which has been supposed hitherto to represent the Jordan, but which is really another and distinct member of the Cambrian.

It was for the purpose of seeking for evidence of this thin sandstone in the Minnesota valley that the recent examination was made. At Shakopee there is no direct evidence of this sandstone. All the evidence there is, is that derived from the deep wells, which barely mention it; but it is well known that a thin stratum of sandstone, only five to ten feet thick, might be pierced by a drill in sinking a deep well, without the knowledge of the operator, the difference in the *chuck* of the drill, and the frequency of pumping not being sufficient to detect it when the underlying and overlying strata were similar and somewhat arenaceous limestones.

However, at a short distance above Shakopee, at the Louisville lime-kilns, and between them and the river, before the appearance of the Jordan sandstone in the river, this limestone underlying the city of Shakopee is significantly divided into two parts, each part extending horizontally over considerable distances, forming a marked terrace-flat. These parts exhibit different outward lithological aspects and intimate stratigraphic structure. The upper one is that which is wrought for quicklime at the lime-kilns at Louisville, and rises to the hight of 75 to 100 feet above the other. It is set off markedly from the other by a bluff which is composed largely of river-terrace gravel, and is so hid by this material that its existence is known only at a few places. It apparently exists as island-like remnants in this region, since it was not found in Mr. Jacob Thorn's well situated in section 15, Jackson, Scott county, just east (a little north) of the quarries at Louisville, which went through gravel and sand 130 feet, blue clay 4 feet, and then entered a reddish limerock in which the drill was working at a depth of three feet at the time of this visit, and which is the equivalent of the lower reddish rock seen in the terrace that separates the limekilns from the river. The thickness of limerock involved in this upper terrace of Louisville cannot be seen to exceed 30 feet, but it rises, apparently, about as high as the top of Mr. Thorn's well, and may exceed that thickness. The stone is very irregular in its bedding, and like the real Shakopee limestone, answering to the descriptions given before of the exposures at Shakopee, at (or near) Quincy, in Winona county, and at Northfield. The beds undulate, swell out, anastomose, become vesicular, then compact, change to shale which is green, are interbedded with shale, etc., etc., and do not resemble at all, except in general chemical constitution, the main body of limestone along the Mississippi bluffs. These rough upper beds swing back from the river in their line of strike, a little to the northeast of Merriam Junction, and are not known to occur in outcrop again, in their entirety, in the Minnesota valley. These are the beds which properly and correctly represent the Shakopee limestone, and they manifest their tendency to retreat from sight here, and further up the Minnesota valley, in the same manner as they have been seen to do in all places in the Mississippi valley. It is the lower limestone, that which forms the lower terrace at Louisville, which returns in force along the Minnesota valley above the rapids near Carver. The only evidence, at Louisville, of the existence of any intervening sandstone consists in the fact of the separation of this formation into two terrace-like expanses, one of which continues thence invisible, and the other extends as an independent formation as far as Mankato. The disintegrating action of a few feet of crumbling sandstone in an otherwise homogeneous limestone formation, along a great valley of erosion is a well-known agent in causing the retreat of the upper portion, in its line of strike, further away from the river. When the beds overlying the sandrock are themselves more irregular and likely to be carried away on the removal of the crumbling sandrock, the retreating habit of these upper layers is easily accounted for.

The limestone in the lower terrace, west from the Louisville kilns, is reddish, resembling the rock at Kasota, and rises about forty-five feet above the flat on which the Minneapolis & St. Louis railroad passes from Carver, about a quarter of a mile distant, on its course to Merriam Junction. By reason of the dip this also soon passes off eastward, giving place to the Jordan sandstone, which is exposed conspicuously in many places. In regular order, the dip continuing in the same direction, the lowermost limestone appears at St. Lawrence, about four miles further west. At Belle Plaine the salt well struck no limestone. The river runs over the St. Croix, presumably, for several miles above Belle Plaine, the beds of which are so erosible that they do not make their appearance through the heavy drift-sheet which prevails generally in that part of the state. Not mentioning the conjectural exposure of rock in the bluff at Rocky Point, near Blakeley, which was not visited on the recent trip, the next appearance of the limestones of the valley is on the west side, where, at Faxon, and again at points somewhat further south, in Jessenland, are outcrops of thin-bedded limerock, as recorded in the second annual report, which appertain, with great probability, to the horizon of the St. Lawrence limestone. There is no further outcrop, so far as known, before reaching Ottawa, where the beds that are the equivalent of the layers of the lower terrace at Louisville return and are wrought by numerous quarries. Considerable time was spent in examining these quarries, where may be found some remnants of the Cretaceous filling cavities in the older rock in the same manner as at Mankato. These quarries show all the characters of the stone quarried at Kasota. They are underlain by a white sandstone, which displays itself in the bluff to the thickness of fifty-five feet (including the talus), at the quarry of Mr. Schwartz, three-fourths of a mile below the station. This sandstone contains isolated patches and also some thin leaves or laminations of green shale which fades to white. It was evidently deposited in an agitated water, as it exhibits sudden changes in the sedimentation-lines, and even contains angular fragments of itself, one and two inches across, that are discordant with the enclosing sedimentation. It may be on the parallel with that conglomerate seen at the crossing of Van Oser's creek, near Louisville, in the upper part of the Jordan sandstone, where (recently) were seen some pebbles of red granite over an inch in diameter, and scales of ochery shale, or rusted soft rock, embraced in the white sandstone.

The limestone quarried at Ottawa lies in heavy but undulating layers, similar to those at Kasota, and furnishes a good building stone. These are near the bottom of the limestone to which they belong. The Shakopee beds probably exist in the eastern and southern (higher) portions of the Le Sueur drairie, which thus repeats the upper prairie at Louisville; while the flat on which Ottawa is situated owes its existence to the same cause as the lower terrace at Louisville.

After another interruption of five miles the same horizon returns at St. Peter, the beds having a fair exposure in the low river bluffs near the asylum. At the highway bridge at St. Peter there is no limestone preserved, the bluff on which the bridge rests at the west end consisting wholly of sandrock. On the top of this sandrock is a thin deposit of reddish shale which amounts to about four feet, as it can be traced back from the river up a little ravine. Back from the river it is lighter colored. This is believed to be Cretaceous, though there is no evidence of it except its anomalous stratigraphic position. It may be a representative of the shale overlying the Jordan sandstone at the cement works at Mankato, though at no other point, north of the cement works, has such a shale been seen immediately overlying the Jordan—not even in the northern confines of Mankato. The limestone beds overlying this sandstone were not re-examined. Some information concerning them can be found in the twelfth annual report, at page 12, where the record of the hospiral deep well is printed. It is probable that No. 3 of that record is the true St. Lawrence limestone, but that it was not wholly a magnesian limestone; also that the St. Peter rock, as quarried at the asylum, is the equivalent of the Kasota and Mankato quarries, and that hence the true Shakopee beds will be found in the upper prairie level back of the asylum, into the composition and origin of which those beds enter with the same agency as at Louisville and at Ottawa. Indeed, the prevalence of large northern boulders on the hillsides and on the upper prairie flats back of St. Peter points to the same cause as where they are strewn over the Shakopee terrace, between Shakopee and Louisville, and at other places that could be mentioned, where the immediate cause thereof is known to be the underlying firm beds of magnesian limestone. The sandstone seen at the old asylum quarry in 1873 (see the second annual report, p. 132), is also now regarded as Cretaceous. It has not been seen since 1873, but the sandstone of the lower Cretaceous is well known to cover all the lower palæozoic strata unconformably, in this part of the state (see the report on Blue Earth county, vol. i, final report), and traces of it are visible as far north as the quarries at Louisville, where pockets of white sand are found in the upper portion and are reported on the top of the quarried beds of the Shakopee. Similar patches of arenaceous Cretaceous are found at the asylum farm near St. Peter, and were fully identified as such in 1873. Second annual report, p. 177.*

The river only intervenes between St. Peter and Kasota, and all the characters seen at the former place are repeated at the latter.

From Kasota to Mankato, a distance of six and a half miles, no great change is apparent. The St. Peter and Kasota terrace continues all the way to Mankato, and its uniform composition is manifested not only by the outward terrace-like aspect, but by several important quarries, and by exposures along the river bluff, intermediate. The difference between the limestone at Kasota and Mankato is only one of thickness. At Mankato the bluff contains an aggregate of about sixty feet of the limestone corresponding to the limestone of the lower terrace at Louisville, and at Kasota this limestone shows not more than twenty-one feet. In both cases they lie on the Jordan sandstone.

The most interesting observations respecting these limestones were made at Mankato. In the first place, owing to the great thickness of the quarried beds, it was probable that the terrace north from the city was nearly on the level of the supposed thin sandstone stratum which had been presumed to exist between the true Shakopee limestone and the beds there quarried. Hence a careful search was instituted for traces of this sandrock. It was not long before angular or sub-angular masses of white arenaceous quartzyte were met with in traveling over the prairie north from Mankato, resembling the angular pieces that have been described at about the same horizon, weathered out from this sandstone in Winona and Houston counties. In several places were found bared spaces of this white hard sandrock, or quartzyte, forming the natural surface of the prairie, this being wholly above the beds quarried at the city. In several other places still further north were found isolated low mounds of magnesian limestone rising three to six feet above the rest of the prairie, while about their flanks, near the level of the prairie, were bare areas of the same flat-lying, white, hardened sandrock, so situated as to show that it continued uninterruptedly beneath, and formed the base of the mounds. These mounds are therefore remnants of the true Shakopee limestone, and this hardened white sandstone, here not more than four feet in thickness, and sometimes wanting entirely by reason of the surface destruction due to the action

* Capt. Beatty states that there is a large deposit of sandstone, more or less disintegrated, probably of Cretaceous age, in the bluffs east of the railroads at Mankato.

of the river in early times, is the western extension of the thin sandstone which had been so often described in counties further east and styled Jordan. Still further north, and a little further from the river, the limekiln which was formerly owned by George C. Clapp, sec. 17, Kasota, is probably based on the limestone overlying this sandstone, and hence on the true Shakopee. Further evidence of the parallelism of these upper beds with the true Shakopee consists in the fact that the fossil described in the twelfth annual report, *Cryptozoon minnesotense*, is found in loose weathered fragments on the prairie on which these mounds occur, evidently from these strata, and it has before been found only in the Shakopee at Cannon Falls and at Northfield.

In the light of these facts, all the topography and geology of the Minnesota valley are in harmony with themselves, and with the same in the Mississippi valley. Some changes must be made in the designations applied in the first volume to the limestones in both valleys, and new designations must be found for the two new strata thus added to the geological column. The following general diagrammatic section will express the correlative geology of these beds in the two great valleys:

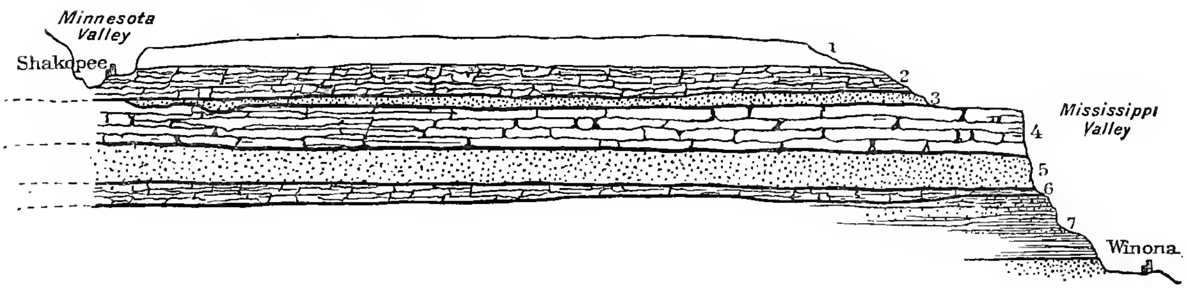


FIG. 1.

Explanation.

1.	Drift and Trenton and St. Peter	
2.	Shakopee limestone	20–40 feet.
3.	White sandstone	0–40 feet.
4.	Magnesian limestone	75–175 feet.
5.	Jordan sandstone	75–100 feet.
6.	St. Lawrence limestone (shaly)	0–30 feet.
7.	Sands and sandy shales	at least 200 feet.

Notes on the foregoing figure: The St. Croix formation includes all below No. 4, and extends down to the great sandstone which is struck in deep wells at Red Wing and Lake City, and appears at Hinckley and in the gorge of the Kettle river in Pine county. This lower great sandstone is more likely to be the Potsdam of New York state than the sandstone No. 5, or any part of this section.

No. 2 is the Shakopee limestone at Shakopee, as there exposed, and as described in the counties in the southeastern part of the state, in the reports of progress and in vol. 1 of the final report. It is the limestone burned for quicklime at Northfield and at Louisville. It is the same as the Willow River limestone, of L. C. Wooster. (Geol. Wis., vol. iv, p. 106.)

No. 3 is a white sandstone which has not, till recently, been identified in the Minnesota valley, but it has been described erroneously as the Jordan sandstone in the southeastern part of the state. It was first described at Lanesboro, in 1875, under that name, but as the Jordan sandstone lies lower it is obviously necessary to find some other designation for this member. In the report of the Wisconsin geological survey for 1877, Mr. L. C. Wooster describes a similar white sandstone in the upper part of the Lower Magnesian, near New Richmond, in Wisconsin, and remarks that this may represent the Jordan sandstone of Minnesota (as the Jordan had then been described in Fillmore and Houston counties), but he applied no designation. However, in the final report of the Wisconsin survey (vol. iv, pp. 106, 127), Mr. Wooster applies the term *New Richmond beds*, to this sandstone, and that term might be extended, being prior in its correct application, to this sandstone in Minnesota.

No. 4. This is the limestone which is generally known as the Lower Magnesian. It was supposed, till lately, to be the actual extension of the St. Lawrence limestone into the eastern part of the state, and has been so named in the reports of progress, and in vol. 1 of the final report. It has never received a distinguishing appellation—except that Prof. R. D. Irving has styled it the "Main body of limestone" (*Am. Jour. Sci.*, June, 1875, p. 440), though at Madison, where this term was applied, it is no more than 85 feet thick. It is the limestone which forms the lower terrace at Louisville, is wrought at Ottawa, appears at St. Peter, and extends conspicuously along the Minnesota river from Kasota to Mankato. Along the Mississippi it forms the precipitous escarpments at the tops of the bluffs.

No. 5. The Jordan sandstone is the uppermost member of the St. Croix. The name Jordan was applied to this in 1873, in the annual report of that year. Prof. Irving has named it Madison sandstone in Wisconsin. (*Am. Jour. Sci.*, June, 1875, p. 440.) This sandstone has been correctly described throughout the Minnesota valley in all the reports of progress, but it was wrongly identified in the eastern part of the state.

No. 6. The St. Lawrence limestone was so named in the report of progress for 1873. It is the same that Prof. Irving named, in 1875, "Mendota limestone." This limestone is unfavorably exposed in the Minnesota valley. Its greatest thickness, known there, is only about 15 feet, but it seems to extend, with some shaly components, distinctly over a thickness of about 30 feet in the Mississippi valley; while, if the shaly beds with which it is associated, and into which it seems to graduate, be included under this term, it will include beds to the amount of nearly 200 feet. This is the chiefly fossiliferous portion of the St. Croix formation. It is found at Red Wing to contain some uew fossils, described in the twelfth report. It is quarried at Lake City, and contains *graptolites*, and at Hokah, where it affords *Dikelocephalus*.

No. 7. These shales and shaly sandstones graduate upward into the St. Lawrence limestone, as above mentioned. They are underlain by a gray micaceous sandstone which is known recently as the *Dresbach sandstone*, from a town in Winona county, where it is wrought for construction.

There are, therefore, in Minnesota and Wisconsin, three magnesian limestones and four saccharoidal sandstones, not including some shales and lower sandstones, involved in regular alternation, thus:

	St. Peter sandstone.	
	Shakopee limestone. "Lower Magnesian" in part.	
	New Richmond beds (sandstone).	
	Main body of limestone. "Lower Magnesian" in part.	
St. Croix.	Jordan sandstone.	"Potsdam" of the Wisconsin geologists.
St. Croix.	St. Lawrence limestone.	"Potsdam" of the Wisconsin geologists.
St. Croix.	Shales.	"Potsdam" of the Wisconsin geologists.
St. Croix.	Dresbach sandrock.	"Potsdam" of the Wisconsin geologists.
	Shales.	"Potsdam" of the Wisconsin geologists.
	Hinckley sandrock.	"Potsdam" of the Wisconsin geologists.
	Red shales and red sandrock passing into the Cupriferous.	
	New Ulm and Pipestone quartzytes (Potsdam).	

In the calculation of the recession of the falls of St. Anthony the value of the early drawings and paintings became apparent, and some of them have been reproduced, as permanent data in the discussion. The writer has tried to examine every representation of the falls prior to 1856 of which he could get any information, and some of this information was obtained after the text of the volume was printed. Hence no reference will be found to two of the plates included.

Plate Y is an enlargement and correction of a small plate published in the fifth annual report, intended to represent approximately the position of the falls at different dates since their discovery.

Plate Z is a reduced copy of a map obtained at Washington through the courtesy of the chief of engineers. The scale of distances on this plate is destroyed by the reduction. The names of all the islands are different from those applied to them by the residents a few years later. That which is here called Spirit island is a low island that consists mainly of debris, but having a solid sandstone foundation, now known as Cataract island. It is sometimes connected with the larger island, here named Cataract island, and at the present time has become probably permanently a part of the larger island, by the process of filling and dumpage incident to the mills, as shown on plate Y.

Plate A^1 was constructed from data obtained after the text was printed. The triangulation carried on by the United States coast and geodetic survey serves to correct the first estimate given for the distance from the falls to Fort Snelling. Prof. Hoag's result makes the distance from the line of bluffs of the ancient gorge at Fort Snelling to the brink of the falls eight miles and thirteen hundred feet. This change will but slightly reduce the results obtained in the calculation.

Other views of the falls. Capt. D. S. Harris, of Galena, Illinois, has an oil painting made by H. Lewis, whose lithographed representation of 1848 is shown in plate T. This painting was "made in 1849 or 1850." It shows Spirit, Cataract and Hennepin islands. Nicollet and Boom islands are undistinguishable from Hennepin. The old government mill is seen on the west side, and the stakes set by Franklin Steele marking the limits of his "claim" on the east side. The view is nearly from the front, but off the west shore, showing an Indian sitting on the rocks in the foreground, similar to that of Lœman's in this respect. Numerous fallen rock-masses are at the foot of the falls. An Indian canoe is crossing the river above the falls.

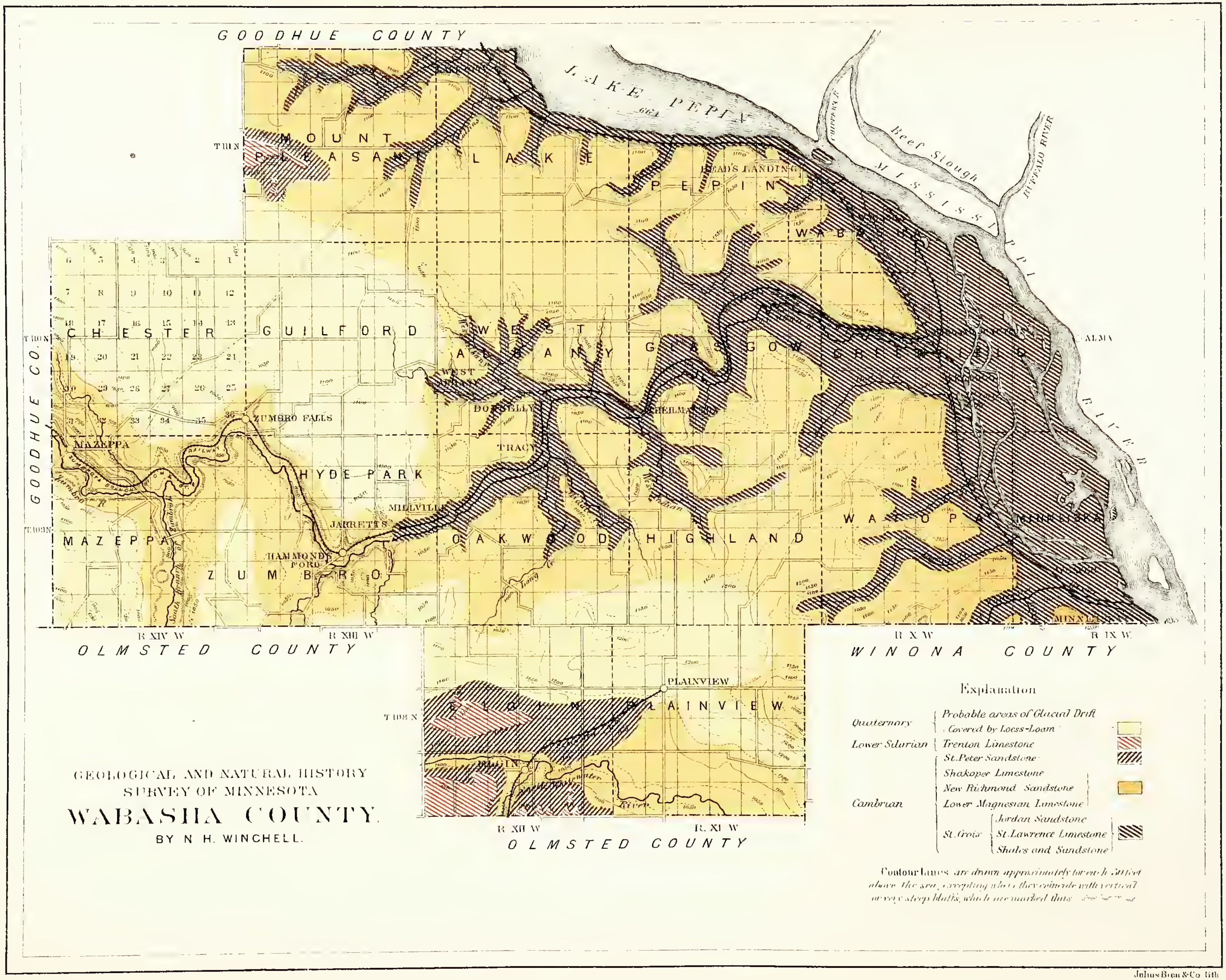
Through the aid of Rev. E. D. Neill, D.D., the writer was very kindly furnished an old drawing made in 1838 by a lady on the occasion of a visit to

Fort Snelling. This pencil sketch, while valuable as a souvenir, did not furnish data that could be employed in this discussion. This old sketch is now in the possession of W. H. B. Custis at Accomac C. H., Virginia.

The painting made by George Catlin in 1835, catalogued in the list of his paintings in the Smithsonian report for 1885 is not included in the collection in possession of the Smithsonian Institution [letter of G. Brown Goode, dated Aug. 8, 1888], but a small engraving of it can be seen on plate 230 of his work entitled *Letters and notes on the manners, customs and condition of the North American Indians:* published in London in 1842. This view is from the right bank about a mile below the falls. It represents the fall as divided into two unequal parts by an island that lies nearest the east shore and extends a considerable distance above the brink. A low alluvial island is in the river below the brink just to the west of the foregoing, now probably represented by Cataract island; and still further west, and nearer the observer, is a high island doubtless now known as Spirit island. The plat of R. A. Colby (see plate Z), represents the same islands in 1842, but the name of Spirit island is placed on Cataract island. These islands are wooded, but the adjacent country is represented as a prairie. In plate 239 Catlin represents the process of making the portage of St. Anthony falls, by a lot of Chippewas. This portage is along the east shore, a point of interest bearing on the proper understanding of Carver's illustration of the falls.

Search was made in the archives of the engineer department at Washington for the illustration of the falls by J. N. Nicollet, mentioned by him in his report intended to illustrate his map (see plate 7, vol. i) in 1842, but without success.

N. H. W.



Julius Bien & Co. lith.

CHAPTER I.

THE GEOLOGY OF WABASHA COUNTY.

By N. H. WINCHELL.

Wabasha county, represented by plate 32, lies in the eastern part of the state, bordering on the Mississippi river and the southeastern extremity of lake Pepin. Its area is 380,562.24 acres, of which 25,018.07 acres are covered by water. This water surface consists of the meandered area of the Zumbro river, and that part of the Mississippi and lake Pepin which lies on the west side of the "center of the main channel." The principal towns are Wabasha, the county seat, and Lake City, both situated on the banks of the Mississippi river. Elgin, Mazeppa and Zumbro Falls are flourishing villages more remote from the great river, the first being on the Whitewater river in the extreme southern portion of the county and the others on the Zumbro river in the western part of the county.

SURFACE FEATURES.

Natural drainage. The surface waters all reach the Mississippi river, which lies from four hundred to five hundred feet lower than the general upland surface of the county. These waters gather first into the Zumbro river, which meanders in a broadly serpentine course eastward to the Mississippi, crossing the entire county. The main affluents of the Zumbro are from the south, being the south branch of Zumbro river, Long creek, Middle creek, West Indian creek, Dady's creek, and Indian creek. From the north the Zumbro receives Skillman brook and West Albany creek. These streams all flow with considerable descent and rather uniform volume of water, but in the early summer are subject to sudden floods from heavy rain showers. These floods are the more likely to be sudden and disastrous since the valleys of the streams are deep and rock-bound gorges; gathering the surface waters, which cannot anywhere be detained on the uplands, owing to the absence of lakes and marshes, and the easy slopes which allow them to run off at once, as so many funnel tubes. These discharge into the main Zumbro valley which, as the main artery, widens toward the east and increases to very great dimensions. The valley itself is from one to two miles wide, between the rock-bluffs, and the stream overflows a wide marge on both sides. In the southern part of the county the North Whitewater river flows eastwardly through Elgin and Plainview.

Water-power mills in Wabasha county.

On sec. 19, Chester, Skillman Bros.; small mill, with 11 ft. head (dam), on Trout brook, often known as Skillman brook.

On sec. 31, Guilford, is the *Cold Spring mill;* the head of water is eight feet, formed by a dam in a small creek, owned by M. S. Hostetter, two run of stone (one for feed). This mill takes its name from a large spring of very cold water which issues from the bluff a short distance below the dam.

At Mazeppa, the Mazeppa mill company own a mill which is situated on the Zumbro river, and has a water head of eighteen feet. It is a roller mill and, by the use of steam, when the water is low, has a capacity of 650 barrels per day.

Jarrett's mill is at Jarrett's ford, N. W. ¼ sec. 23, Hyde Park, on the north side of the Zumbro river. It is a custom mill with three run of stone (one for feed), twelve feet head of water, and is operated by a race-way from the river; owned by Mr. Owen.

On the West Albany creek are John Hoffman's mill, with two run of stone for custom work, and E. Brandt's mill with two run of stone for custom work.

At Millville, a fine water-power is available. A seven foot dam would give a fall of fourteen feet, capable of running twenty-four run of stone.

Another good power exists at Zumbro Falls, where was formerly a mill.

On Indian creek, sec. 24, Watopa, is a small mill owned by John Hitchcock. It has about twelve horse-power, with a fall of ten feet; two run of stone for flour, one being an "automatic mill" for grinding middlings; of Knowlton and Dolan, Logansport, Ind.; one Leffel wheel.

On Dady's creek, N. E. ¼ sec. 34, Greenfield, is Mark Hitchcock's mill. This has a turbine wheel of eighteen inches, but cannot run constantly; one run of stone; twelve horse-power.

On West Indian creek, sec. 16, Highland (Theilmanton P. O.), S. Appel owns a flouring mill with two run of stone, of which one is for feed. It has a turbine wheel, with twelve feet head of water. Another good power is two miles below Appel's mill, where formerly was a mill. This is in the west part of sec. 5, Highland.

Topography. Wabasha county, particularly in the eastern half, participates in the general character of surface that is typical of the "driftless area," so-called. The valleys are deep and rock-bound, though the ruggedness of rocky bluffs is alleviated by the heavy covering of loam with which the whole county is mantled. The valley of the Zumbro is one of the chief elements in the topography of the county. This valley is so wide and so deep that it suggests a history of erosion and a force of water once operating in it which have no adequate proportion to the small stream that now occupies it. The streams that now discharge into it add material to the flood plain of the main valley, while the Zumbro itself seems to be unable to carry away the detritus they bring into it. The valley is therefore apparently being filled rather than excavated. Along the immediate river banks, within the general margin of the rock-bluffs, is a belt of alluvial flat land which lies about 400 feet below the upland plateaus north and south. This alluvial flat is sometimes two miles wide, and in the lower part of the valley is terraced by successive flats higher and higher above the river, the highest being at Kellogg, sixty-five feet above the depot, or 767 ft. above the sea.

These upland plateaus are undulating, or rolling, their roughness increasing with proximity to the little water-courses. These smooth undulations are due partly to the changes of the strata of the underlying rocks, partly to the incomplete filling up of pre-existing rock-gorges by the deposit of the loam, or the drift, and partly to the effect of drainage and re-excavation since the deposit of the loam. Nowhere are these irregularities of surface so disposed, at this time, as to enclose lakes. If such lakes were ever so produced in Wabasha county they have been drained by the wearing down of their original outlets. The nature of the contours, however, warrants the belief that Wabasha county never was diversified by lakes, but the surface on which the loam was deposited was one that had been for many ages sufficiently eroded by drainage to prevent the accumulation of standing waters; the loam itself accommodating itself to the original contour, and on being brought finally to constitute the surface of the county, taking the same, or nearly the same, plan of drainage.

From the foot of lake Pepin, near Reed's Landing, the Mississippi valley, in its course in Wabasha county to Minneiska, exhibits some interesting features.* At the foot of lake Pepin is the mouth of the Chippewa river of Wisconsin. This river drains a region of wide extent and carries to the Mississippi a large amount of debris. Much of this debris consists of siliceous insoluble materials

*Compare "*A Canoe Voyage up the Minnay Sotor.*" Featherstonhaugh; and "*Report of a geological reconnaissance made in* 1835, *from the seat of government by the way of Green bay and the Wisconsin territory to the coteau de prairie,*" by the same author, p. 132. Also general G. K. Warren's report on *Bridging the Mississippi river*, 1878; Appendix X3, of the report of the chief of engineers.

derived from the sandstone formation which forms the basis rock of a large area in Wisconsin east of the Mississippi, and when it reaches the wider channel in which the Mississippi flows, it is precipitated to the bottom, filling up the Mississippi channel. This has been going on so long that a very marked difference has been produced in that portion of the channel of the Mississippi immediately below the mouth of the Chippewa. The channel is choked with islands and sand-bars, rendering navigation difficult, the average slope of the water-surface is increased, so that wherever the water finds passage between these islands it flows with greater rapidity. This accumulation is so great that it has choked up the direct course of the Zumbro river, on the west bank, causing that stream to take a serpentine course through the alluvial deposits for a distance of eight miles, after entering the valley, before it reaches actually the waters of the Mississippi. At the same time the waters of the Chippewa itself are set back and are compelled to spread over a wide area in Buffalo and Pepin counties, Wisconsin. At times of flood in the Chippewa, which come earlier and more suddenly after heavy storms in the Northwest than in the Mississippi proper, at this latitude, the Chippewa river discharges a large amount of water through its eastern delta-arm, known as Beef slough, and then the Chippewa and the Buffalo rivers combine in one volume before they join the Mississippi.* This deposit of alluvium at the mouth of the Chippewa is so great that the Mississippi itself is partially dammed up, causing the spreading of its waters, above the mouth of the Chippewa, over the whole width between the rock bluffs, producing lake Pepin.

Mr. G. W. Featherstonhaugh seems to have been the first to assign this cause to the existence of lake Pepin. The following is an extract from his geological report of 1835.

G. W. FEATHERSTONHAUGH ON THE ORIGIN OF LAKE PEPIN.

At the southernmost end of lake Pepin, Chippewa river comes in on the left bank, a stream of considerable magnitude, from four to five hundred yards wide where it joins the Mississippi; the volume of water is said to be great for sixty miles. Having passed its mouth the scenery becomes changed, and, instead of a valley two or three miles wide, full of low wooded islands, lake Pepin presents itself, a sheet of water about twenty miles long and nearly three miles wide, upon an average, perhaps. This is nothing but a continuation of the Mississippi valley, without any islands, with this difference, that the river occupies

* On early maps the Chippewa and the Buffalo rivers are confounded, and represented as one. This may have been due to the fact that they then had but one point of debouchure, and that the present principal outlet of the Chippewa into the Mississippi is of more recent origin. For further facts bearing on this supposition see the report on Goodhue county. In a similar manner the Whitewater and the Zumbro are not kept distinct by the early voyageurs.

all the space between the banks, whilst the bluffs and coulees present themselves with the same general character as below. Why there are no islands in this part of the valley, and why it is a lake, deserve an inquiry. It will occur to every observer, that the entrance of a stream of such magnitude as the Chippewa river, coming in at right angles to the Mississippi, must necessarily dam up the water above it. Thus, at the general subsidence of the water-level, when the alluvial bottom of the other part of the valley would be left dry, and plants begin to grow, it would here be covered up to the northwest for a great distance, whilst the wind and high waves to which this lake is now so much exposed as often to make the passage a dangerous one, would keep the alluvial matter in a state of suspension, and finally, wearing it away. the whole breadth of this part of the valley would be necessarily covered by water. This is the way in which I would account for the origin of this lake, the only one in the whole course of the river."

General G. K. Warren, whose long-continued acquaintance with the hydraulics of the Mississippi renders him one of the highest authorities on this subject, has expressed a similar opinion of the effect of the Chippewa in producing the sheet of water known as lake Pepin. But he views the operation from a different standpoint from Mr. Featherstonhaugh. He looks at the Mississippi valley as slowly being filled up by washing detritus from the surrounding uplands, and Mr. Featherstonhaugh regards it as undergoing erosion and excavation by the current of the river. The following is an extract from his *report on the bridging of the Mississippi*, in 1878.

GEN. G. K. WARREN ON THE ORIGIN OF LAKE PEPIN.

The next considerable tributary to the Mississippi valley is the Chippewa. This, entering at right angles with a steep river slope and a probable high-water volume of 40,000 cubic feet per second, comes from a region inexhaustibly supplied with siliceous sand and gravel containing a considerable of the heavy magnetic sand whose oxidation often cements the other sand deposits.* It brings quantities of these materials, which, spread out below, give a very steep slope to the Mississippi river and very bad shoals for navigation.

Lying just above this point is lake Pepin which it completely accounts for. The reason this lake has not been filled up by the Mississippi above is that the supply of sand from the Chippewa is so great as to raise the level more rapidly than the filling above can keep pace with. The Chippewa from the left bank pushes its sand-bar out so as to confine the outlet to the lake to the opposite shore. There is an observable relation between the condition of the lake and the deposits of the Chippewa. The deepening of the waters by the deposit of Chippewa sands is felt at low water sometimes as far up as the mouth of the St. Croix when floods in the Chippewa make these deposits large, and, on the other hand, in times of droughts, the waters of the lake cut the outlet deeper, and lower its level so that the shoal water is moved down the river two or three miles below the St. Croix.

If we follow the Mississippi down we find similar conditions produced by the Wisconsin river as by the Chippewa; that is, a great increase of the slope and shoaling of the water below the jnnction, with gentler slopes, deep water and lake-like aspect above. There would probably have been a large lake here if the discharge of the Black river, just above, had not silted it up.

Another instance is afforded by the damming-back effect of the Mississippi deposit at the mouth of the Illinois river, making it at low water almost like a lake up [to] La Salle.

Lake Pepin must therefore be regarded as due to the deposit by the Chippewa of heavy coarse sediment into the valley of an ancient and larger river. This view may be strengthened further by the

*"The analysis of the soil on this part of the Chippewa river (the Yellow Banks) gives 93 per cent. of insoluble matter. which is chiefly white sand, with only two per cent. of organic matter, less than four per cent. of soluble saline matter, consisting chiefly of oxide of iron and alumina, with only a trace of calcareous earth." Owen's final report, p. 56.

following considerations: It lies immediately in the course of the main valley above an important tributary. In this respect it agrees with Lac-qui-parle, on the Minnesota, just above Lac-qui-parle river; with another lake on the same valley just above the Yellow Earth river; with Big Stone lake, in the same valley, just above Whitestone river; with lake Traverse, which is formed by deposits from a stream at each end, and this empties sometimes in both directions. It agrees in this relation with the lakes on the Qu'Appelle, which all lie just above a considerable tributary, and with like lakes on the upper Fox, of lake Winnebago. This constant relation seems unmistakably one of cause and effect.

Valley now filling up. From what has been stated above, it is clear that the river valley, in the part we have considered, is not now being deepened by erosions, but, on the contrary, is filling up; and it appears to be doing so all along its present course, except at the rapids.

Elevations. Lake Pepin is 664 feet above the sea at average tide-level, and the Mississippi river at the southern boundary of the county is 650 ft., the river falling fourteen feet in the distance of about eighteen miles. The highest land in the county is about 1200 feet above tide. Such elevation is reached in the western part of Mount Pleasant, and in the south-western part of Elgin, in each case lying over a small area of the Trenton limestone. There is another area of equal elevation north and northwest of Plainview, extending somewhat into Elgin and Highland townships. It is presumed that this last is produced by an accumulation of drift-clay, below the loam, rather than by the preservation of any part of the Trenton formation. A tongue from this area extends southeastward into Winona county, in Whitewater township, and there it is highly improbable that any part of the Trenton exists.

Elevations on the river division of the Chicago, Milwaukee and St. Paul railway, in Wabasha county.

	Miles from St. Paul.	Feet above the sea.
Lake City,	58	705
Reed's Landing,	68	682
Wabasha,	70	712
Midland Junction,	75	695
Kellogg,	76	702
Weaver,	84	674
Minneiska,	87	672

Elevations on the Minnesota Midland railway, a branch of the Chicago, Milwaukee and St. Paul railway.

Derived from profiles in the office of Geo. H. White, engineer, Minneapolis.

	Miles from Wabasha.	Feet above the sea.
Midland Junction,	5.1	695
Glasgow,	11.8	716.5
McCracken,	16.7	732
Theilmanton,	19.3	743
Tracey,	22.3	756
Keegan,	24.2	759
Millville,	28.1	787
Garrett,	30.7	792
Hammond,	33.3	805
Funk,	36.7	820.5

	Miles from Wabasha.	Feet above the sea.
Zumbro Falls,	40.8	836
Summit, grade,	46.8	895
Depression, grade,	48.0	868
Mazeppa,	51.2	935
Forest Mills,	57.4	970
Summit, grade,	58.8	986
Zumbrota,	59.0	980

According to the profile of the railroad from Eyota to Plainview, the elevation of Plainview depot is 1167 feet above the sea; Elgin, 1069 ft.; Whitewater creek, 1055 ft., and Viola station, 1129 feet.

Mean elevation of Wabasha county. The various townships of the county may be estimated to have the following average elevation above the sea, viz.: Mount Pleasant, 1100 feet; Lake, 1000; Pepin, 1050; Wabasha, 740; Chester, 1025; Guilford, 1100; West Albany, 1000; Glasgow, 915; Greenfield, 800; Mazeppa, 950; Zumbro, 1050; Hyde Park, 1025; Oakwood, 985; Highland, 1025; Watopa, 900; Minneiska, 675; Elgin, 1125; Plainview, 1135. If Lake and Wabasha together be taken as the equivalent of one town, with areas proportioned as three to one, and Pepin and Minneiska be considered together equal to another town, each forming one half, the mean elevation of the county will be found to be about 1065 feet.

Soil and timber. Where the surface is not broken by too great ruggedness, as it is in proximity to the numerous ravines and along the bluffs of the Zumbro and the Mississippi, the soil is uniformly good; and even when the roughness is quite unfavorable, or the sides of the hills are quite steep, the soil still is capable of producing all the crops of ordinary agriculture. The loam which spreads over the entire county is strong and fertile in all the qualities of a good soil. It is only in the immediate vicinity of the sandstone bluffs that the soil is too light for reliable farming. In these places the sand is superficial, and has worked down from the bluffs since the deposition of the loam which in many cases is seen to underlie the sandy surface. The loam itself is not sandy, in general, but clayey, and is easily carried in suspension by moving water. Yet in its ordinary condition it is hard to get into suspension. It is impervious. The rains that fall upon it are more effective in disturbing it, and removing it, in the act of falling, than in the erosion that follows. An ordinary sand or gravel would be easily undermined and carried to lower levels by the surface wash that sometimes is poured upon this loam, while the loam can be attacked by erosion only on its very surface. It is so fine, and so tenacious, that the surface film susceptible of such attack is very thin. If the surface be covered by vegetation the loam is practically immobile under ordinary rains and wash.

Trees. The following trees were seen growing native in Wabasha county. They are named in the estimated order of abundance.

Quercus tinctoria, *Bart.* Black oak.

Quercus macrocarpa, *Michx.* Bur oak.

Populus tremuloides, *Michx.* Aspen. [Generally called "popple." These three species apparently constitue nine-tenths of all the trees.]

Acer dasycarpum, *Ehrh.* White or silver maple.

Negundo aceroides, *Mœnch.* Box elder.

Quercus alba, *L.* White oak.

Ulmus Americana, *L. (Pl. Clayt.) Willd.* Amerian elm. [One tree in the bottom-land of the Zumbro, at Kellogg, measured ten and a half feet in circumference, four feet above the ground, rising a hundred feet or more.]

Tilia Americana, *L.* Bass.

Populus grandidentata, *Michx.* Great-toothed poplar.

Populus monilifera, *Ait.* Cottonwood. [Grows very large in the bottom-land of the Zumbro near Kellogg.]

Acer saccharinum, *Wang.* Sugar maple.

Prunus serotina, *Ehrh.* Black cherry.

Ostrya Virginica, *Willd.* Ironwood.

Pirus coronaria, *L.* American crab-apple.

Prunus Americana, *Marshall.* Wild plum.

Prunus Pennsylvanica, *L.* Wild red cherry.

Juglans cinerea, *L.* Butternut.

Betula papyracea, *Ait.* Paper or canoe birch.

Ulmus fulva, *Michx.* Slippery or red elm.

Fraxinus Americana, *L.* White ash.

Amelanchier Canadensis, *Torr. and Gray.* Juneberry.

Carpinus Americana, *Michx.* Water beech.

Salix nigra, *Marshall.* Black willow.

Juglans nigra, *L.* Black walnut. [At Read's Landing.]

Fraxinus sambucifolia, *Lam.* Black ash. [At Kellogg.]

Ulmus racemosa, *Thomas.* Rock elm.

Celtis occidentalis, *L.* Hackberry.

Cratægus Crus-galli, *L.* Cockspur thorn.

Cratægus tomentosa, *L.* Black thorn.

Pinus Strobus, *L.* White pine. [Grows on the banks of the Zumbro at Kellogg, and is common in cultivation.]

Fraxinus viridis, *Michx. F.* Green ash. [This may be more common than is here presumed. It was identified only at Kellogg, but it is possible that it was often taken for white ash.]

Carya alba, *Nutt.* Shagbark hickory. [Read's Landing. This is near its northern limit. Indian Creek.]

Mr. Jos. Hammond, of Hammond's ford, enumerates five oaks that he thinks native to the country, viz.: bur, white, black, red and yellow. "The yellow is what his mother used to tan his breeches with when he was a boy, and differs from the black only in having a yellow inner bark."

Shrubs. Corylus Americana, *Walt.* Hazelnut.

Rhus glabra, *L.* Smooth sumac. [Common.]

Rhus typhina, *L.* Staghorn sumac. [Rare.]

Rhus Toxicodendron, *L.* Poison ivy.

Xanthoxylum Americanum, *Mill.* Northern prickly ash.

Rosa blanda, *Ait.* Early wild rose.

Rubus villosus, *Ait.* High blackberry.
Rubus Canadensis, *L.* Low blackberry.
Rubus strigosus, *Michx.* Wild red raspberry.
Rubus occidentalis, *L.* Black raspberry.
Spiræa opulifolia, *L.* Nine-bark.
Vitis cordifolia, *Michx.* Grape.
Ampelopsis quinquefolia, *L.* Virginia creeper.
Ribes floridum, *L.* Wild black currant.
Ribes Cynosbati, *L.* Gooseberry.
Sambucus Canadensis, *L.* Elder.
Lonicera parviflora, *Lam.* Small honeysuckle.
Celastrus scandens, *L.* Bittersweet.
Cornus circinata, *L'Her.* Round-leaved cornel.
Cornus paniculata, *L'Her.* Panicled cornel. [Common.]
Cornus sericea, *L.* Silky cornel.
Cornus stolonifera, *Michx.* Red-osier dogwood.
Cornus alternifolia, *L.* Alternate-leaved cornel.
Viburnum Lentago, *L.* Sweet Viburnum.
Smilax rotundifolia, *L.* Common greenbrier.

THE GEOLOGICAL STRUCTURE OF WABASHA COUNTY.

The rocks of this county occupy the same horizon as those of Winona and Houston counties.* They range from the Trenton downward to and including a part of the St. Croix. The accompanying map of the county, plate 32, is colored to show the distribution of these formations at the surface. There is also a color intended to show the probable area of the drift (till) where it exists beneath the loam, but the boundaries of this last are largely conjectural. The drift is known to exist at certain places, but it cannot be said to be known to exist over all the areas that are represented as drifted, though it is highly probable that it does,—and also very probably extends in small patches still further east, the topography being uniform.

The order of the formations in the county is shown in the following list:

Trenton limestone.	Silurian.
St. Peter sandstone.	
Shakopee limestone.	Cambrian.
New Richmond sandstone.	
Lower Magnesian limestone.	
Jordan sandstone,	
St. Lawrence limestone.	

* Volume I, pp. 208 and 236.

The Trenton limestone. Of this formation only the lowest portion is represented in Wabasha county. There is an isolated elevation, or group of mounds, the principal one known as *Lone mound*, in the western part of Mount Pleasant, extending westward into Belvidere, Goodhue county, which contains the Trenton limestone. This rock is in the summits of these mounds and might be quarried profitably.

In the vicinity of Elgin, also, are several other outliers of the same kind, rising conspicuously above the level of the adjacent land. The same rock occupies the upper portion of these mounds. The largest of these is southwest from Elgin and extends into Olmsted county where it is hid by drift accumulations, but is thought to be continuous to near Rochester, and indeed becomes a part of the general Trenton area of that county. There are several quarries in the Trenton a mile or two south of Elgin, situated in Olmsted county, which supply stone used at Elgin for foundations and bridges. There is also possibility of the existence of the Trenton in the high land north and northwest of Plainview.

The St. Peter sandstone. This is seen exposed in numerous places in the slopes of the mounds that have been mentioned in Mount Pleasant and Elgin townships. Two singular isolated mounds of the St. Peter are also on the S. E. ¼ of sec. 27, Zumbro, rising about seventy feet higher than the surrounding country, (1050 feet above the sea) though not higher than much of the surface in Hyde Park. It probably extends much more widely than the map of the county represents, occupying some of the area that is shown as drift-covered. It is sometimes struck in sinking wells in the region north of Plainview. This formation does not, apparently, differ from the descriptions that have been made of it in other counties. Its thickness seems to be about 100 feet.

The Shakopee limestone. This portion of the upper Cambrian as a distinct stratum seems to be present in the western part of the county, appearing in the bluffs of the Zumbro in the same manner as in the banks of the Root river at Lanesboro, in Fillmore county. At Millville the bluffs are divided into two distinct perpendicular escarpments, each of limestone. The interval separating them is turfed over, and amounts to about thirty-five feet, exhibiting in places a good deal of sand. The exposed part of the Shakopee overlying this interval rises about twenty-five feet, or 178 feet above the depot at the same place, or 965 feet above the sea. Mr. R. C. Stillman at Plainview, a practical well-digger, states that the first rock struck under the loam, over a large area in that part of the county, is a limestone which has a thickness of thirty-five feet. This is followed by an interval of white sandrock amounting to about twenty feet; and that by another limestone which amounts to about 150 feet. These are average statements for the region between the Whitewater and the Zumbro. At Elgin the depot is about five feet below the top of the Shakopee.

The New Richmond sandstone. This formation has been seen exposed at but one point in Wabasha county. Its wide extent, however, is sufficiently proven by the foregoing statements of Mr. Stillman concerning wells drilled about Plainview. Further, it is indicated, as in Winona county generally, by the occasional occurrence of sink-holes in regions where they cannot be attributed to any other cause. Such are found along the highway between Read's Landing and Lake City. Its thickness is from twenty to thirty feet.

In the southeast quarter of sec. 27, Chester, are several flat-topped mounds, from which the drift seems to have been removed. They are along the road from Mazeppa to Bear Valley post office. They resemble mounds that have been described in speaking of the Trenton, in other counties, but are less high. They are topped with a magnesian limestone which has, remaining, a thickness of fifteen or twenty feet. In the slopes is a crumbling white sandrock, which here represents the New Richmond beds.*

Southwest from Read's Landing, in ascending the hill along the road to Lake City, emerging from the valley of the Mississippi, a lot of large sandstone masses appear near the top of the bluff, thrown out by the grading of the road. They appear in the same situation as others that have been noted in Houston and Winona counties;† and as there is no reason to expect the St. Peter sandstone in that locality, and as the general

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* Similar Shakopee mounds are described in Olmsted county, vol. i, p. 335. The high country, northeast of the Trenton area, in Plainview, seems to be due to a S. W. dip in the Cambrian, causing it there to rise higher. The term New Richmond in this volume signifies the same as the term Jordan in vol. i. See the 14th annual report, p. 325.

† Final report vol. i, pp. 221, 253.

level rises from fifty to seventy-five feet still higher, toward the southwest, exhibiting the topography characteristic of the Cambrian in southeastern Minnesota, the only plausible explanation of these blocks is to refer them to the weathered edge of the Richmond sandstone. This point is nearer the actual river-valley of the Mississippi than any point at which this sandstone has, hitherto, been reported.*

The Lower Magnesian limestone. As in other counties in southeastern Minnesota this stratum of the Cambrian is the most conspicuous feature along the bluffs and ravines. It constitutes the larger part of the perpendicular limestone wall that often is seen rising high above the valley, and giving prominence and form to the angles of the bluffs that project beyond the underlying strata. In some places it is likely that such bluffs will be found to include also the New Richmond and Shakopee, especially in the central and western portions of the county, while along the lower reaches of the Zumbro valley and along the Mississippi this formation is alone found capping the bluffs.

At the village of Millville there are irregular patches and beds of sand in the lower portion of this limestone, varying from a few inches to four feet in thickness, the St. Croix sandstone below being fully set in and rising about twenty feet above the level of the water.

On sec. 19, Chester, the Lower Magnesian is very siliceous with coarse, cavernous, geodic concretions, and with masses of spongy silica. This crystallized silica is very handsome when it is cleaned. Sometimes large surfaces, over a foot across, coated with drusy, amethystine crystals are exposed by the breaking off of the rock. Sometimes the silica is chemically united with the lime and other elements, forming layers of nodular chert. This is supposed to be in the upper part of the formation, and higher than the beds that are most wrought for building-stone at Frontenac, and can be compared to the *brecciated and concretionary* masses seen at Stockton and elsewhere in Winona county, in the same formation.† At the same place this rock is conglomeritic, the pebbles being wholly of fine-grained limestone, and sometimes over an inch across. The cement of this conglomerate is a light-buff, fine oölyte, which also itself sometimes appears to be fragment-

* Compare, however, the report on Goodhue county.
† Final report vol. i, p. 254.

ary. The oölitic structure penetrates the chert sometimes, and even the conglomerate pebbles are seen adhering to the chert after it is detached. Below this concretionary portion about six feet of more regular layers suitable for quarrying can be seen at Mr. Skillman's (sec. 19) on Trout brook. When rusted and cemented, these have a very deceptive resemblance to the upper beds of the St. Croix crumbling sandstone.

The Lower Magesian is not much quarried in Wabasha county. It has been used somewhat at Mazeppa for quicklime by E L. Ford, and at Millville a small church and a store have been erected of stone from it. At the latter place the bridge piers are built of the same stone. The qualities that have made the "Frontenac stone rank among the best building stones" of the country extend over a large area in Wabasha county, west and southwest from Frontenac, as may be seen in large, fine blocks, falling from the bluffs in section 4, Mount Pleasant, and at other points.

The St. Croix formation. The thickness of this formation in Wabasha county amounts to two hundred and fifty or three hundred feet. Its particular stratigraphic composition is not known to vary from that which has been given for it in Winona county. Its lowermost strata so far as exposed are seen to consist of shale and shaly sandrock along the Mississippi river, where cut by grading for the railroad, rising from twelve to fifteen feet above the track. These beds are supposed to be some portion of No. 6 or No. 7 of the Winona county section.*

Overlying these shales is a thickness of loose, massive sand, amounting sometimes to seventy-five feet, and above this is found the stone which is quarried at Wabasha and Lake City. In the quarry of Edward McKeefry, at Wabasha, are seen numerous specimens of graptolites. Joseph Baker's is in the same beds. The quarries at Read's Landing are in the same kind of stone as those at Wabasha and Lake City, and are situated below a massive crumbling sandrock, the top of which rises about 320 feet above the grade of the railroad or 1025 feet above the sea. At Lake City the sandrock rises 265–275 feet above the railroad. The quarry of Baker Harrison, at Central Point, in Goodhue county (near Lake City), is in *Sugar-loaf mound*, an isolated fragment of the line of diminishing bluff between the lake and a tributary of Gilbert's creek. It embraces only the shaly and sub-calcareous layers, lying below a thickness of seventy-five to eighty feet of loose sand near the top of the St. Croix and seems to be covered by the same horizon as that shale in which are found

* Final report vol. i, p. 258.

the trilobitic remains at Red Wing.* There is a shaly belt of similar rock running along the top of the quarry, but no fossils could be found in it. This is the same horizon, also, as Whitman's quarry at Hokah, Houston county.

The immediate bluffs about Kellogg are low, rising 250–300 feet, and consisting entirely of the St. Croix sandstone. The full thickness of the overlying limestone is found only at some distance further back. At the same time the bluffs are all evenly rounded off and covered with turf, with little exposure of the rock.

In the state of Wisconsin this horizon of argillo-dolomitic beds quarried at Wabasha, Reed's Landing and Lake City, has been distinguished by Prof. R. D. Irving with the name *Mendota limestone*, and the overlying sandstone, separating it from the Lower Magnesian, has been by him named *Madison sandstone*, and they were both referred to the horizon of the *Lower Magnesian*, of Dr. Owen. Prof. Chamberlin, however, while recognizing the distinctness of these parts, assigns them to the so-called *Potsdam*, of Wisconsin, which he extends upward to the top of the *Madison* beds, the point that has been recognized by geologists very generally, as the bottom of Dr. Owen's *Lower Magnesian*.† There can be no question on the part of anyone who has examined the bluffs of the Mississippi in Minnesota, that Dr. Owen included these subdivisions in his "lower sandstone," and that they were recognized by him in his general section of that formation.‡

These distinctions, however, are the same that were made at an earlier date by the writer in the second annual report of the Minnesota survey, and they are the equivalents of the terms St. Lawrence and Jordan as used in this volume, both being included in the St. Croix formation. [See the fourteenth annual report, p. 325.]

Cretaceous. There is some reason to believe that there are some outliers of Cretaceous in Wabasha county, although no known exposure of these strata can be referred to. Mr. Joseph Hammond once obtained a quantity of white clay by the roadside, at some point north of Guilford Corners, by the old road to Lake City, and exhibited it at Lake City. Mr. Hammond, when applied to, cannot exactly locate the spot, but says "it was down a long hill, or descent, in a gully caused by water," and thinks it "runs quite a distance." Owing to the existence of Cretaceous but few miles further north, in Goodhue county, there is no *a priori* improbability of its having extended formerly as far east as Guilford in this county.

THE DRIFT.

Till. There is a blue, stony clay underlying large areas in Wabasha county, including the most of Chester and Guilford, and the highlands in

* Compare the report on Goodhue county.

† *Geology of Wisconsin*, vol. ii, p. 260.

‡ Compare *Report of a geological survey of Wisconsin, Iowa and Minnesota*, p. 52. In this general section the "Madison sandstone" is embraced in *e* and *f* (sixth trilobite bed), and the "Mendota limestone" in the upper member of *d* (the fifth trilobite bed).

Mazeppa, Zumbro, Elgin, Plainview, and Highland. It is probably more extensive still, running into Lake and West Albany, and even into Pepin, but its limits cannot be defined with certainty. It is hid by a canopy of yellow, fine loam. Its former existence over areas that now do not show it, is proven by the occurrence of an occasional foreign boulder in the ravines where every other trace of it has been destroyed. How thick this clay may be is unknown, but it seems to be, in some places, from twenty-five to forty feet. Indeed, in digging a common well, at two miles south from Plainview, Mr. R. C. Stillman reports that he found rock only after passing to the depth of ninety-seven feet. Of this twenty feet were in loam, and the rest in this stony blue clay with boulders. The region between the Clearwater and the Zumbro rivers, however, does not generally have this blue clay, the loam only being found in deep wells, and having an average thickness of about thirty-five feet. The existence of this clay at Plainview, determined the final site of the village. The village was first started two miles further east, under the name of Greenville (in 1855), but as no good wells were found the town was unsuccessful; while at Plainview, the blue clay there present furnished water at about thirty feet and attracted new settlers and even the residents from Greenville. In this clay is frequently found wood and other vegetation.

Wells in Wabasha county.

The following facts respecting common wells in this county have been obtained mainly from Mr. R. C. Stillman, of Plainview.

Elgin. P. Ryder, three and a-half miles north of Elgin village: well, 270 feet deep; in the earth, 80 feet; rock, 190 feet.

J. Gregor, three and a half miles north of Elgin village: well, 174 feet deep; black soil, 1½ feet; yellow loam, 20 feet; hardpan, 73½ feet; sandrock, 48 feet; limerock, 31 feet; depth of water, 31 feet.

Fred Hample, six miles northwest of Elgin village: well, 140 feet deep; black soil, 3 feet; yellow loam, 10 feet; sand, 10 feet; blue clay, 12 feet; limerock, 30 feet; sandrock, 25 feet; limerock, 50 feet; depth of water, 70 feet.

J. Titheringtnn, two and a quarter miles southeast from Elgin: well, 80 feet deep; black soil, 6 feet; red clay, 8 feet; yellow loam, 5 feet; hardpan, 21 feet; limerock, 40 feet; depth of water, 15 feet.

H. G. Richardson, one mile northeast from Elgin village: well, 29 feet deep; black soil, 3 feet; yellow loam, 13 feet; limerock, 60 feet; sandrock, 4 feet; depth of water, 29 feet.

O. V. Rollins, one-half mile north from Elgin village: well, 119 feet deep; black soil, 2 feet; yellow loam, 12 feet; sand, 6 feet; gravel, 3 feet; limerock, 23 feet; sandrock 3 feet; limerock, 78 feet feet; depth of water, 78 feet.

E. Ordway, at Elgin village: well, 39 feet deep; black soil, 2½ feet; blue clay, 7½ feet; sand, 4 feet; sandrock, 6 feet; sand and clay, 8 feet; sand and gravel, 11 feet; depth of water, 8 feet.

Cheese factory, at Elgin village: well, 22 feet deep, driven; black soil, 2½ feet; yellow loam, 17½ feet; gravel, 2 feet; depth of water, 4 feet.

C. Richardson, at Elgin village: well, 20 feet deep, driven; black soil, 4 feet; yellow loam, 14 feet; gravel 2 feet; depth of water, 5 feet.

Geo. Bryant, at Elgin village: well, 50 feet deep; black soil, 3 feet; yellow loam, 15 feet; lime; rock, 22 feet; sandrock, 10 feet; depth of water, 20 feet.

Oakwood. L. M. Gregg, five and a half miles northwest from Plainview: well, 288 feet deep-black soil, 2 feet; yellow loam, 36 feet; limerock, 62 feet; sandrock, 24 feet; limerock, 142 feet; sandrock, 3 feet; limerock, 14 feet; sand, 5 feet; depth of water, 125 feet.

A. P. Foster, three and a half miles northwest from Plainview: well, 217 feet deep; black soil, 2 feet; yellow loam, 20 feet; gravel, 10 feet; blue clay, 7 feet; gravel, 2 feet; limerock, 50 feet; sandrock, 10 feet; limerock, 106 feet; sandrock, 10 feet; depth of water, 25 feet.

Highland. E. C. Geary, five and a half miles north of Plainview: well, 290 feet deep; black soil, 2 feet; yellow loam, 16 feet; blue clay, 3 feet: limerock, 63 feet; sandrock, 24 feet; limerock, 132 feet; sandrock, 50 feet; depth of water, 22 feet.

Plainview. Henry Wedge, two miles south of Plainview village: well, 307 feet deep; black soil, 4 feet; yellow loam, 20 feet; blue clay, 69 feet; limerock, 206 feet; sandrock, 8 feet; depth of water, 135 feet.

A. G. Felton, at Plainview village: well, 303 feet deep; black soil, 3 feet; yellow loam, 16 feet; blue clay, 6 feet; hardpan, 11 feet; limerock, 80 feet; sandrock, 25 feet; limerock, 150 feet; sandrock, 10 feet; depth of water, 160 feet.

D. R. French, two and three-fourths miles east of Plainview village: well, 276 feet deep; black soil, 4 feet; yellow loam, 34 feet; limerock, 60 feet; sandrock, 25 feet; limerock, 126 feet; sandrock, 27 feet; depth of water, 45 feet.

J. A. Matthews, two and a half miles east of Plainview village: well, 258 feet deep; black soil, 5 feet; yellow loam, 31 feet; limerock, 50 feet; sandrock, 35 feet; limerock, 102 feet; sandrock, 35 feet; depth of water, 41 feet.

L. Porter, five miles southeast from Plainview village: well, 282 feet deep; black soil, 3 feet; yellow loam, 9 feet; sand, 2 feet; yellow loam, 8 feet; hardpan, 20 feet; limerock, 220 feet; sandrock, 20 feet; depth of water, 45 feet.

L. Sextoo, three and a half miles southeast from Plainview village: well, 179 feet deep; black soil, 2 feet; yellow loam, 18 feet; hardpan, 20 feet; gravel, 2 feet; limerock, 127 feet; sandrock 10 feet; depth of water, 10 feet.

C. Fisk, one-half mile north of Plainview village: well, 214 feet deep; black soil, 3 feet; yellow loam, 18 feet; limerock, 93 feet; sandrock, 20 feet; limerock, 53 feet; depth of water, 54 feet.

William Dewitt, two miles southeast from Plainview village: well, 205 feet deep; black soil, 4 feet; yellow loam, 18 feet; blue clay, 4 feet; limerock, 15 feet; sandrock, 100 feet; limerock, 64 feet; depth of water, 70 feet.

A. Stoltz, one mile north of Plainview village: well, 220 feet deep; black soil, 2 feet; yellow loam, 20 feet; gravel, 3 feet; blne clay, 15 feet; limerock, 180 feet; depth of water, 50 feet.

C. Donaldson, four and a-half miles south from Plainview village: well, 88½ feet deep; black soil, 1½ feet; yellow loam, 12 feet; gravel, 5 feet; limerock, 29 feet; sandrock, 9 feet; limerock, 32 feet; depth of water, 33 feet.

O. Huntoon, four and three-fourths miles southwest from Plainview village: well, 89 feet deep; black soil, 4½ feet; limerock, 85 feet; sandrock, 4 feet; depth of water, 25 feet.

Mat. Ward, five miles southwest from Plainview village: well, 76 feet deep, black soil, 3 feet; yellow loam, 8 feet; limerock, 65 feet; depth of water, 22 feet.

J. H. Robinson, at Plainview village: well, 40 feet; black soil, 3 feet; yellow loam, 11 feet; blue clay, 12 feet; sand, 2 feet; hardpan, 12 feet; depth of water, 6 feet.

S. Struble, one and a half mile east of Plainview village: well, 30 feet deep; black soil, 2 feet; yellow loam, 4 feet; blue clay, 4 feet; sand, 3 feet; hardpan, 17 feet; depth of water, 17 feet.

J. R. McLaughlin, at Plainview village: well, 36 feet deep; black soil, 1½ feet; yellow loam, 16 feet; hardpan, 18 feet; blue clay, 6 feet; depth of water, 20 feet.

J. J. Butts, at Plainview village: well, 30 feet; black soil, 2 feet; yellow loam, 14 feet; hardpan, 14 feet.

O. Wilcox, at Plainview village: well, 45 feet deep; black soil, 2½ feet; yellow loam, 17 feet; hardpan, 14 feet; blue clay, 13 feet.

J. Hessig, seven and a half miles southeast from Plainview village: well, 25 feet deep; black soil, 3 feet; gravel, 1 foot; limerock, 21 feet; depth of water, 3 feet.

Chester. On section 24, a log a foot in diameter was found in digging a well, twenty feet below the surface. This is on the high prairie. The log was well preserved, and could be chopped. It lay on the ground near the well for some years.

The deep well at Lake City was drilled by Mr. W. E. Swan, and passes through a considerable thickness of drift, showing the great depth of the gorge of the Mississippi river at that place. The depot at Lake City is 705 feet above the sea, and the gorge extends at least 210 feet below that level, or descends to a depth only 495 feet above the sea. The strata passed through are as follows, shown by a series of drillings furnished by Mr. Swan:

		Thickness.	To what depth.
1.	Black soil,	2 ft.	2 ft.
2.	Yellow clay,	40 ft.	42 ft.
3.	Gravel and sand,	160 ft.	202 ft.
4.	Fine loam clay,	5 ft.	207 ft.
5.	Sand (this seems to be the beginning of the rock),	18 ft.	225 ft.
6.	Coarse sand,	7 ft.	232 ft.
7.	Sand,	208 ft.	440 ft.
8.	Sand, rusty, or stained with light red shale,	5 ft.	445 ft.
9.	White sand, grains often fractured, very coarse,	15 ft.	460 ft.
10.	Sand, stained with red shale, and with flesh red grains,	35 ft.	495 ft.
11.	Sand,	5 ft.	500 ft.
12.	Red shale and sand; shale is soft, and has a red powder,	320 ft.	820 ft.

There is a little foreign gravel on the washed surface near the top of the ravine (over the brink of the bed-rock), near the school house, in sec. 28, Pepin.

On the shore of lake Pepin, at Lake City, are large boulders of gabbro, 3-4 feet across.

Several large boulders are to be seen in sec. 18, Guilford, and drift-gravel and stones occasionally everywhere west of that.

A deposit of drift-clay may be seen in the road near Millville.

Drift-clay and gravel can be seen in the southeast corner of Plainview, sec. 25. One large boulder of gneiss lies in the road ou sec. 35.

There is a large amount of foreign drift, in the form of gravel and boulders, about Mazeppa, sometimes also gravelly clay. It is of the color of the loam and is mixed in the bottom of the loam.

Terraces. The Zumbro and the Mississippi are bordered by alluvial terraces. These consist, usually, and conspicuously, of gravel of foreign origin, the washings from the frayed edges of the sheet of till that once seems nearly to have covered the whole county.

At Zumbro Falls there is a sandy irregular terrace (15-20 feet) which, near the bottom, shows sand. In the higher bluffs is coarse gravel, mingled with fallen pieces of the limestone strata; the gravel itself also consisting largely of limestone of the same kind.

The village of Millville is on a terrace that rises thirty feet above the depot, or 817 feet above the sea, and forty-eight feet above the river at high water.

At Kellogg the highest terrace, composed of gravel and sand, is that which accompanies the Zumbro, sixty-five feet above the railroad grade, or 767 feet above the sea, and 106 feet above Lake Pepin. This shows a descent, in this terrace-level, from Millville to Kellogg, of fifty feet. At Kellogg there is another flat forty feet lower, on which the school house stands, and this descends irregularly to the plain ou which Kellogg is situated. The only permanent terrace here is the uppermost one, the other plains apparently being liable to fluctuation, and to blending, by a gradual descent, with the present flood-plain. The top of this higher terrace here is of gravelly sand with but a slight covering of loess.

Along the Mississippi there is an important terrace-flat, rising from forty-five to fifty feet above the river. Kellogg is situated on it, where it seems to be about fifty feet above the river. Wabasha, likewise on the terrace, is fifty-four feet above the river, and Lake City depot is forty-one.

The loess loam. This deposit forms the immediate surface, and apparently the latest formation throughout the county. It has already been referred to as the basis of the soils and subsoils of Wabasha county. This term, as here used, is made to cover quite a variety of composition and possibly of origin which the loess loam exhibits.

Sometimes this loam is stratified and fine, yet exhibiting thin laminæ of sand. Sometimes it is quite sandy and should not be styled loam. In some cases it passes into sand, as seen in some of the cuts in the terraces. Sometimes in the uplands it seems to graduate into pebbly clay, and this into stony clay, and the stony clay then is the *till*, which has been mentioned as underlying the loam. Sometimes this loam is massive and wholly destitute of signs of aqueous action. This structure would result from the decay *in situ* of the rocks underlying the county; and but little if any of such undisturbed, decayed, rock-material can be said to exist in this county. The various conditions of this loam seem to indicate, when carefully studied, a much more varied history and a longer one, for its accumulation, than has generally been imagined. Its substance seems to have been worked over, perhaps several times, by water and by ice, thus reproducing itself with modified features in different localities. Notwithstanding these variations, its usual and characteristic quality, at the surface, is that of a fine, sticky, impervious, yellowish clay.

MATERIAL RESOURCES.

The natural resources of this county are the same as of several other counties in the southeastern part of the state. *The soil* is fertile and apparently very durable, and almost inexhaustible. *The timber* is sufficient for fuel for the residents within the county, and has supplied some hard-wood lumber. The loam is everywhere fitted for making *red brick*. Several establishments were noted, viz.: Ernst Stoll, at Elgin, makes from two to three hundred thousand per year, selling for eleven dollars per thousand, shipping to other towns; mixed wood four dollars per cord, and oak five. At Weaver red brick was formerly made and used in the hotel. The business is now carried on by Hopkins and Johnson. Light red brick are made at Read's Landing and at Wabasha. Soft, light-colored red brick were made formerly at Lake City. At Central Point, William Lutz makes about a hundred and twenty to two hundred thousand per year. For construction of buildings not much *stone is quarried* in Wabasha county. The quarries are all at work on the poor stone which lies somewhat below the top of the St. Lawrence limestone, an inferior stone that should be abandoned, since in the immediate proximity to the same quarries the layers of the Lower Magnesian limestone are accessible—the same beds, and showing often the same superior excellence, as at Frontenac. This use of the inferior stone must have arisen from the greater ease with which the rock could be obtained when the towns were first settled, when, to get any stone for foundations to the cheap structures that were put up, was considered ample and satisfactory. Once started the same openings would naturally be continued until a demand for a better grade of building material should spring up, and some more enterprising owner should offer the better stone in the market. A bed of *porcelain clay* is said to occur in the northern part of Chester and Guilford. This deposit, however, has not been seen by any member of the survey, and this statement is based only on hearsay. It is not improbable that the Goodhue county pottery clay should extend into this county. *Gold* has been washed out of the drift on the S. E. ¼ of sec. 25, Chester, and at other points southeastwardly to Zumbro Falls; also on sections 6 and 27, Mazeppa.

Earthworks. There are numerous remains of the "mound builders" scattered over the county. They are most marked along the Mississippi valley. They have not been investigated by the survey. The site of the city of Wabasha was at first thickly strewn with mounds. Dr. D. C. Estes, of Lake City, testifies that, having opened a number of them, he found generally no relics of artificial manufacture. In one instance he found a few pieces of the well-known pottery, and in another a number of bones. These mounds, which generally were not large, may have been simply the ruins of habitations made of, or at least liberally covered with, mud and turf, of the nature, perhaps, of the more modern adobe of the west and southwest. The city of Wabasha, though named from the Sioux chief of that name, was not the place of his village, which was on the prairie at Winona.*

*See the *Historical Chart*, plate 1, vol. i.; also the thirteenth annual report, page 111.

CHAPTER II.

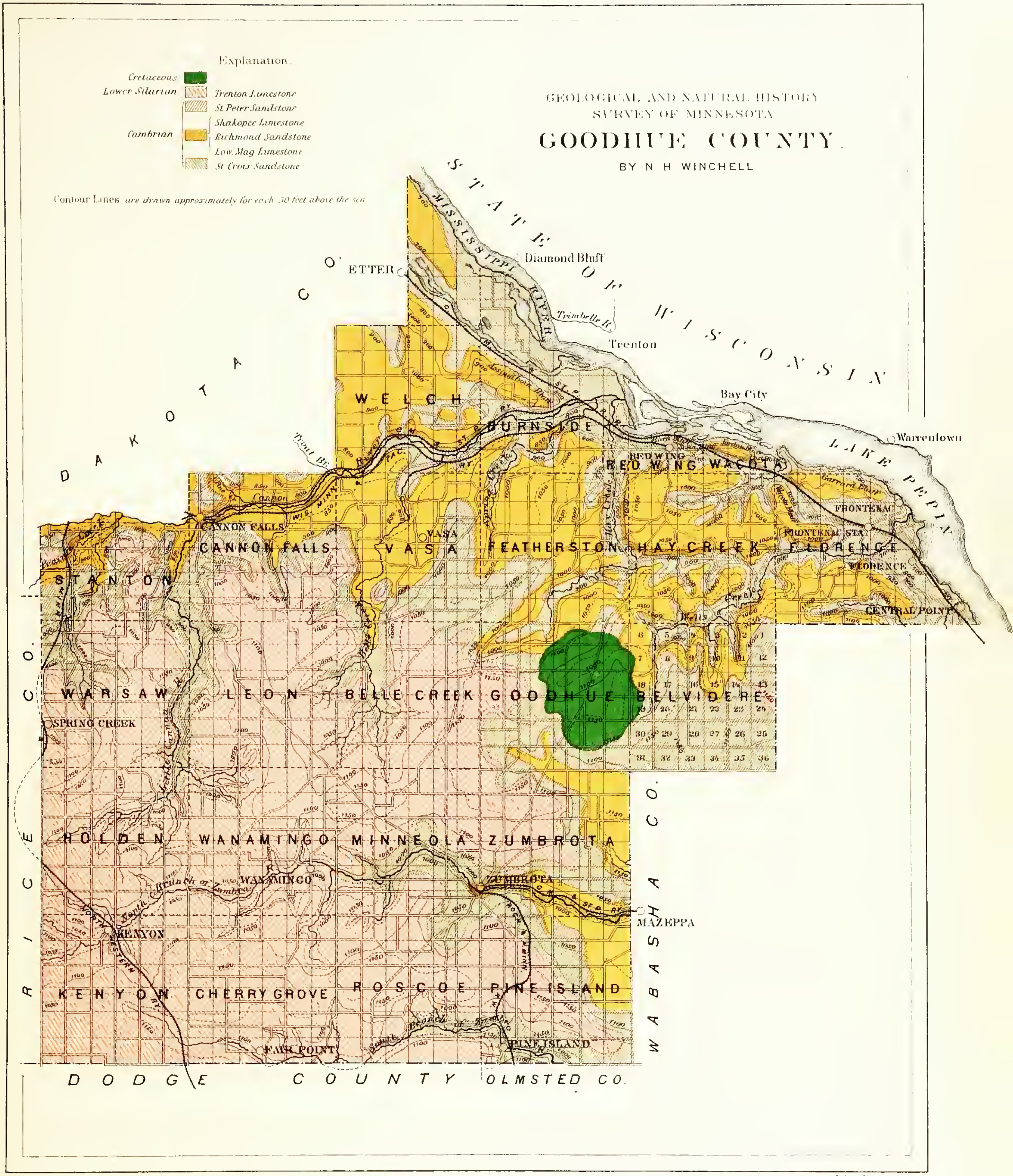
THE GEOLOGY OF GOODHUE COUNTY.

By N. H. WINCHELL.

Situation and area. This county lies next northwest of Wabasha, described in the last chapter, and also borders on lake Pepin and the Mississippi river. It is a large and important county, ranking among the first in the state in point of wealth, population and agricultural products. It contains eighteen entire government towns, and five fractional towns formed by the Mississippi and Cannon rivers. Its total area is 784.79 square miles, or 502,265.62 acres; the water area being only 20.21 square miles, or 12,936.06 acres.

SURFACE FEATURES.

Natural drainage. The surface waters all reach the Mississippi river in an easterly or northeasterly course, descending from the hight of 1,250 feet above the sea, in Kenyon, to 665 feet in lake Pepin, nearly six hundred feet. They gradually pass from a heavily drifted country to one of little or no foreign drift; although still within the region where they join the Mississippi river the bedded rocks are buried under a very copious loam, and the valley itself is bordered by terraces that are composed of northern gravel. The chief of these tributary streams are the Cannon, with its southern arm, the Little Cannon, and the north and north-middle branches of the Zumbro. Belle creek, another branch of the Cannon river, occupies an important valley, running northward from near the center of the county. Spring creek, Hay creek and Wells creek, though not large streams, are important agents in defining the topography of the county, and have subterranean sources of



Julius Bien & Co. lith

supply which keep them at a nearly uniform stage of water through the year, and afford valuable water-powers for flouring-mills.

The county has no lakes. There are a great many large springs issuing from the banks of the streams, giving clear, pure water, which are dependent on the impervious nature of the rocky strata. Some of the tributaries of Belle and of Wells creeks issue thus from the rock-walls of the valley in which they run, having size sufficient, in some instances, to afford available water-power for machinery. The shaly parts of the St. Croix formation seem to be most frequently the cause of these springs. These shaly parts at Red Wing are seen in the bluffs about a hundred and fifty feet above the Mississippi.

Water-power mills in Goodhue county.

On the Cannon river: *Cascade mill*, at the northwest corner of the county, owned by the Cascade manufacturing company; ninety horse-power is used, but the average capacity of the stream is said to be 300 horse-power, and would furnish 500 when three feet more flowage and three feet more tail-way are made use of. The banks are of gravel, but the mill stands on the Shakopee limestone; head of water, 12 feet; capacity, 125 barrels; three run of stone (one also for feed); eleven sets of single rolls; two Leffel wheels, one forty-eight and the other thirty-six inches.

On the Cannon river: *Goodhue mills*, owned by Gardner & Espenscheid, Cannon Falls; fall of water, about ten feet; eight run of stone. Gregg & Company, at Cannon Falls (old mill), ten run of stone, 7½ feet fall of water. On sec. 27, Welch, a custom mill owned by Lowry & Miller, having a dam giving 9 feet of water, with two run of stone for flour and one for feed.

On the Little Cannon river: Thompson & Smith, by means of a dam, at Cannon Falls, obtain a fall of water of 30 feet. They have a 35-inch Flenniken turbine, giving 100 horse-power, and use only 75. The mill has three of Willford's single rollers and three of E. P. Allis, and three of Allis' double rollers; two run of stone; capacity, 240 barrels per day, with an annual product of 20,000 barrels. On the same stream is the *Oxford mill*, sec. 25, Stanton, owned by G. H. Wilcox, having four run of stone, and partly run by steam.

On Belle creek: *Granite mills*, S. Nelson & Company, sec. 16, Vasa; a custom mill, with three run of stone and one set of Gray's patent of Allis' double rollers, giving a product of forty-eight barrels per day. The power is applied by two Leffel wheels, each 26½ inches in diameter. Two dams are needed, one having a fall of 16 feet, and the other 9 feet, the lower dam being connected with the mill by a wire cable.

On Spring creek: *Spring creek mills*, sec. 27, Burnside; Bombach & Herschler; three run of stone (one for feed); custom and shipping mill.

On Hay creek: *Valley mills*, Brash & Ortman, sec. 12, Featherston; three run of stone and a "pair of crushers;" 19 feet fall of water. *Hawkeye mills*, G. F. Meyers, sec. 24, Featherston; three run of stone. *City mills*, Frederic Hack, sec, 36, Red Wing; 10 feet head; three run of stone; shipping mill; capacity, from 20 to 50 barrels in twenty-four hours.

On Wells creek: *Belvidere mill*, sec. 5, Belvidere, N. B. Gaylord; custom mill with two run of stone. *Wells creek mill*, sec. 24, Hay Creek; owned by Geo. Espy; three run of stone and one for feed. *Union mill*, ——— Keys, owner; sec. 20, Florence; four run of stone "and two crushers." *Frontenac roller mill*, Lot E. Gaylord, near Frontenac; 25 horse-power used; two Houston wheels, one 22½-inch and one 20-inch; two run of stone; capacity, 35 barrels in twenty-four hours.

On the Zumbro: *Kenyon mill*, J. A. McReynolds; four run of stone. Sec. 25, Wanamingo; mill here is owned by Nels Oleson, and has two run of stone. At Zumbrota, the mill is owned by E. T. Talbert, having four run of stone and 9 feet head of water. On sec. 26, Roscoe, is a custom mill with two run, and a saw mill, owned by Dan Collins. At Pine Island, Mr. J. K. Wyman has a custom mill with three run of stone. On sec. 29, Zumbrota, Wells & Dickey own the *Forest mills*, with five run of stone.

Topography. The high prairies in the central and southwestern portions of the county present a strong contrast with the hilly tracts in the northern and eastern. The former are broad, undulating, and somewhat monotonous. The winds find no natural obstacles, and the exposed traveler can retire to no sheltered nooks for protection. The latter are broken by frequent and abrupt hills, which rise, with some sheltering timber, from two to five hundred feet above the adjoining valleys. The transition between these extremes is gradual, and is due to a variety of causes. Some of the deep valleys of the northeastern part of the county penetrate, in their uppermost sources, far within the flat and monotonous areas of the county. Such are the valleys of the Little Cannon and of Belle creek. The north fork of the Zumbro, which entirely crosses the county from west to east, in its southern portion, introduces an agreeable diversity of surface westward from Zumbrota, which otherwise would be one of mere open and nearly level prairie. The north-middle fork has the same effect near the southern border of the county, about six miles further south. The townships of Pine Island, Roscoe, Cherry Grove, Kenyon, the central portion of Holden, and the north half of Wanamingo and Minneola, and much of the area of Warsaw, Leon and Belle Creek, and some of Vasa, Featherston and Goodhue, are included in this higher portion of undulating prairie. They are embraced in the areas of the Trenton and Galena limestones, and they are overspread with the older drift-sheet, which, again, has been smoothed off by the loam which everywhere in the county forms the immediate surface and constitutes the subsoil. There are some elevated areas in the central part of Belvidere and Goodhue which are as high, and as typically a prairie, as any that have been mentioned, but their smoothness and greater hight are due not to the existence of these higher rock-strata and the drift-sheet, but to the interposition of another formation, the Cretaceous, prior to the drift-epoch. Indeed it is not known how far, or over how much of the county, this Cretaceous deposit may not extend. It may act an important part even in those higher prairie townships that have been named, but it has not been discovered. This soft and easily destroyed formation has filled up the old gorges in the limestones and sandstones of the Cambrian, in Belvidere and Goodhue, rendering the surface again nearly smooth, and it has escaped destruction at such sheltered points as were out of the reach of the chief lines of drainage incident to the drift-epochs, though it received lightly the overspreading of northern drift or loam common to the whole country.

The uplands of these most elevated portions of the county are from 1150 to 1250 feet above the sea. The streams here are but little below this level. They gradually work to lower and lower levels, becoming larger by springs and tributaries, till they reach the level of lake Pepin, which is 662 feet above the sea. At the same time the uplands that immediately adjoin these streams, even the Mississippi valley itself, do not partake of this gradual slope toward the Mississippi. The Mississippi bluffs are from 1000 to 1100 feet above the sea, or only about 150 feet lower than the average elevation in the southwestern part of the county.

In the northern part of the county the Cannon valley exhibits some of the topographic features that have been mentioned in the report on Fillmore, Houston and Olmsted counties. These are most remarkable in Stanton, Cannon Falls and Vasa, where the Trenton limestone and the St. Peter sandstone are so related to the attenuated drift, and the conjunction of an important valley of erosion, that their characteristic agency in producing strong topographic features is perfectly exemplified. Rounded or elongated knobs and ridges rise abruptly from the plains to the hight of about a hundred and fifty feet, consisting of isolated areas of these formations. The valleys, both large and small, are bounded by such bluffs, while between the bluffs is stretched out a level plain of gravel which winds about all the hills and follows the serpentine course of the main valley, even to the Mississippi—and *there also* still exists as a terrace-flat along the west side of that river.

To a certain extent the same features are brought out by the same forces operating on the alternating limestones and sandstones of the Cambrian, in Welch, Burnside, Red Wing, Featherston, Hay Creek and Florence. But here the knolls are larger and higher and the valleys are not filled so notably with foreign gravel and sand. They constitute a network, as they recede from and encroach on each other, which almost defies any explanation or adjustment with any present or ancient system of general drainage. The formations seem, apparently, to have rotted down *in situ*, and to remain intact in patches and ridges, wherever the accident of superficial wash and erosion was in their favor. The valleys, however, are narrow and abrupt, in comparison with those of the Trenton-St. Peter area, and in proportion to the hight of the bluffs. These forces have left the country, in general, rough or hilly. They are most fully exhibited along the immediate valley of the Mississippi as it passes from Welch township to the Wabasha county line; and they gradually fade out, by the filling up of the valleys, as one travels southwestwardly away from the Mississippi.

The breaking down of the formations, and the erosion of these valleys so far as they are cut in the strata occurred in pre-glacial times, and they are comparable to the gorged and broken condition of the Galena and Trenton formations described in the report on Fillmore county.* Here, however, the drift-sheet was never spread, except as gravel washed from the drift-sheet further west, and the loam deposited subsequently by standing water was not sufficient to level up the surface. When the glacial drainage began to operate, and brought this region under the course of changes incident to the glacial epoch, these pre-existing valleys were some of them filled up, some of them maintained as constant water-courses, some of them shut off from their earlier connections, and some of them extended in new directions. But in the main the erosion of the glacial epoch itself, in Goodhue county, was unimportant in producing these valleys. Its action was rather to modify by its own deposits, to fill in here and not there, to sweep out the rotted and loosened rock in some places and not others, and in its onward momentum toward the Mississippi, to give the topography a more evident stamp of its dependence on that great river. On the shrinkage of the high waters of the glacial epoch, numerous streams were dried, old channels were abandoned, deeper cuts were made by the hastening currents, through the smothering mantle of gravel and loam which had been the product of their own swollen and exultant power. Colonel William Colvill, of Red Wing, has suggested the courses of some of these old streams,† in the following words.

"Hay creek, going upstream, carried one of these currents. The Trout brook, whose branches came down through these magnificent gorges—followed by the roads leading up to Featherston—came, at Porter's tannery, on to the ground now held by Hay creek. The bluffs below the tannery, on that side, are a continuation of the Trout brook bluffs, and beyond the range of Hay creek at any time. At the then mouth of Trout brook, on the river, struck in the current, and soon broke across the narrow

*Final report, vol. i, p. 275.
†Address before the *Goodhue county Old Settlers' Association*, March 7, 1885.

and low divide, into Hay creek, followed along its valley to the Brash mill, sec. 12, Featherston, near its then head, and broke over into the wide and deep valley which there comes down from Featherston,—pointing directly to the great bend of Hay creek. This bend was then a part of the main valley of Wells creek, and the current then flowed down that, now dry, valley to Wells creek mill, on the present stream. With what eloquent tongues do the arid cliffs and isolated peaks of that old dry valley speak. They seem to echo the thundering floods which in those days battered their faces, and like the gigantic bones of an old creation, to tell us the history of the past."

Col. Colvill conjectures, further, that the water of Wells creek was not able then to reach the Mississippi freely, but passed through some of the valleys now tributary to it, southward into some of those that are tributary to the Zumbro, mainly through the valley of Skillman's brook, uniting with the Zumbro at Mazeppa. The disproportion between the size of the Zumbro valley and the drainage area which it now serves has been referred to in the report on Wabasha county, and this hypothesis of Col. Colvill serves to account for some of this irregularity. There would be nothing more probable than that at the flood-time of the glacial epoch a volume of water would be found to accumulate in that depression caused by the easily eroded strike of the St. Peter sandstone, across Goodhue county, having the gently westward-dipping bluff of the Trenton limestone on the west. This is because all the formations dip toward the southwest. It will be observed that this supposed passage of volumes of water across the eastern part of Goodhue county, into Skillman brook, coincides roughly with the then probable strike of the St. Peter sandstone. There is still observable by one passing southwestwardly, a perceptible valley running southeastwardly, outlined on the west by the Trenton bluffs, all the way from northeastern Vasa to southeastern Zumbrota.*

Another probable water-course, which is now abandoned, was from Cannon Falls northeastwardly. The observer is struck with the narrowness of the Cannon valley at once on passing Cannon Falls, as compared with the width of the low, flat valley lying next north. It is probable that much of the water of the Cannon, in glacial times, passed north of the bluffs that lie next north of the village. Some of it re-entered the Cannon valley again about the mouth of Belle creek, by way of Trout brook, and some of it passed northeastward to the Mississippi at Etter, the same place where the Vermilion waters entered it. The descent of this northeastern flat to Etter is about one hundred feet for the uplands, but three or four hundred feet for the valley in which the waters were collected.

Changes of level in lake Pepin.

Allusion has been made, in the report on Wabasha county, to fluctuations in the level of lake Pepin. There are old stumps of trees in the bottom of the main channel, at Red Wing, showing that the surface of the river there was once lower than now. Col. William Colvill, of Red Wing, has thus spoken concerning these fluctuations: †

"The Chippewa bar has perhaps several times since the glacial age, by changes of that river from its present to its 'beef-slough' outlet and back again, undergone changes of level, attended

* First annual report, pp. 46 and 47.

† Loc. cit.

with a backing up of the Mississippi as high as above suggested. We know that even the little cyclone of last year, which spent its fury along the upper waters of the Chippewa, caused the water of that stream to reverse the current of the Mississippi for miles above this place, and that two or three feet above the usual stage of the season have since been maintained here by the additions to the Chippewa bar that were at that time laid down. The stumps of large trees, still standing where they grew, now seen in the main channel of the river below low-water mark, between here and the head of the lake, attest the much more considerable changes which accompanied the last transfer of the Chippewa outlet from the beef slough to the present foot of the lake. From the maps and descriptions of the French explorers, the foot of the lake was in their time at the beef-slough outlet, at least ten miles below the present, the head of the lake being then the same distance below its present head. The Sioux Indians have traditions to the same effect, and also that when they came here to live the head of the lake extended above Barn bluff, so that they used to ruu their canoes the entire distance from Red Wing to Frontenac in that interior channel. From that time to the present the bar has of course been gradually wearing away. In the year 1727 the French built a fort near Maiden rock,* on a 'long point,' in the 'dense woods,' at a hight, as they were assured by those well acquainted with the river, at a safe distance above high water. The next spring they were drowned out of the fort, and at length obliged, by continued high water, to remove to this side of the lake, at Frontenac. At the time of this flood the Winona prairie was also completely submerged — which has not occurred since. This shows an extraordinary storm, which was probably the same that caused the last transfer of the outlet of the Chippewa. There is now no 'point of land' near Maiden rock, nor any extent of land below the present beach that ever permitted the growth of timber of the character specified. It is now, along the beach, a steep slope, covered with rocks, with a dry sandy soil. The native trees are 'black jacks,' thinly scattered. To this day the lake covers the greater part of the site of that fort."

The Chippewa proper, in early maps and descriptions, is styled *Beef river*, or "Des bœufs," from the abundance of buffaloes generally met with there; but this name (Buffalo) is now applied to a small stream entering the lower end of the beef-slough, near Alma. This name was perhaps formerly meant to apply to the whole river emptying there; but since the change in the place of outlet, has come to signify the small stream only. Again, Hennepin, as well as La Salle, says that the party dispatched by La Salle explored this river "ten or twelve leagues." There must have been some reason why this, of all the rivers that enter the Mississippi mentioned by them, should be the only one of which they could say anything of their own knowledge, above its mouth. It may be supposed that the course for canoes ascending the Mississippi was through this retired channel of the Chippewa from the south end of Beef slough to near the present mouth of the Chippewa, and that this passage in the Chippewa, was amplified into an "exploration" of ten or twelve leagues.

SURFACE FEATURES OF THE VARIOUS TOWNSHIPS.

Stanton may be divided into river-terrace and upland, the greater portion of it being of the former. There are two, and in some places three, distinct terraces which are practically level, extending along both sides of Prairie creek and Cannon river. The latter valley is frequently more than a mile wide, and embraces large and valuable farms. The upland is undulating, and has a soil similar to that of the terraces, although its subsoil is usually clayey rather than gravelly. There is timber along the Little Cannon, and sparsely on Prairie creek.

Warsaw has nearly the same surface characters as Stanton with more undulating upland. It is a fine prairie town, but has a good supply of timber for fuel along the Little Cannon river, which runs in a deep, terraced valley with abundance of Trenton limestone in the upper bluffs.

Holden. This township has some of the highest land in the county. It is mainly an undulating prairie, but is much diversified through the central portions by the head waters of the Little Cannon and its tributaries. It has patches of small timber in various places in the upland, and considerable areas of larger forest in the northeastern part, and along the Zumbro in the southern part.

Kenyon is the highest town in the county, has an undulating surface, which was originally almost wholly prairie, and some timber along the north branch of the Zumbro, in sections 7, 3, and 13. It has occasional small sloughs, with turf-peat, in the uplands, but in the summer season they are dry, and furnish a coarse hay.

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* *Neill's history of Minnesota*, fourth edition, appendix H. This was Fort Beauharnois; compare plate i, of vol. i, final report. The high water was April 18-30, 1728. [N. H. W.]

Cherry Grove is also a high prairie town, with low, broad undulations of surface. The drainage is toward the north and south, from the elevated central portion. The Zumbro, in the southern part, has rocky banks, and is accompanied by timber.

Wanamingo is crossed east and west by the north branch of the Zumbro, but the valley is broad and with gentle slopes. This township is mainly one of prairie, but has timber along the Zumbro, and in secs. 5 and 6 in the northwest corner of the town. It has an undulating surface.

Leon has more large timber than any town in the county. It is in the western and northern portions, where the gentle slopes of the Little Cannon, and of its tributaries, over the Trenton shales, seem to superinduce, as in other parts of the county, those favorable conditions that have promoted the growth and preservation of trees. The town is undulating and well watered.

Cannon Falls is like Stanton, and is marked by sudden changes of level. The outer bluffs of the Cannon valley are frequently more than a mile apart, and over two hundred feet above the water in the river. In this valley are broad terraces and beautiful farms. The town has considerable timber, ranking next to Leon. Along some of the valleys the St. Peter has produced a marked effect in giving a sandy lightness to the soil, and some of the roads are very bad for that reason.

Welch. This lies chiefly on the north side of the Cannon river, and adjacent to the Mississippi river. It is much broken, but rarely rocky, except along the immediate bluffs. The valleys are generally richly alluvial, but in the north part of the town the valley which is tributary to the Mississippi at Etter is gravelly and sandy, with terraces scantily clothed with crooked oaks and bushes.*

Vasa is intersected by the valley of Belle creek, north and south, which is accompanied by timber in the northern part of the town. There is also a little timber in sec. 33, and small areas in other parts, but by far the largest part of this township is an undulating prairie. In secs. 19, 30 and 31 is a high table-land.

Belle Creek is, in general, about 150 feet higher than Vasa, and is crossed, north and south, by Belle creek valley, which, with its tributaries, introduces considerable diversity of surface in the western part of the town. There is timber in secs. 1, 2, 3, 4, 8 and 17. The rest is an undulating high prairie.

Minneola is crossed by the north branch of the Zumbro, and has great differences of level. The highest land is in the northwestern part of the town, and the lowest is in the valley at Zumbrota; but the changes are very gradual, excepting in the immediate descents into the Zumbro valley, making in general an undulating surface. This town is almost destitute of timber.

Roscoe has an abundance of timber in the southern tier of sections, through which passes the Zumbro river. With that exception it is very similar to Minneola.

Pine Island, in its eastern portion, is underlain by the upper Cambrian limestones and sandstones. which, in connection with the attenuation of the drift, makes a broken and wooded surface, somewhat lower, and greatly in contrast with the most of the county. Still, on account of the thick loam, the underlying rock is rarely exposed. Sections 4, 5, 7, 8, 9 and 17 also have a considerable small timber The valley of the Zumbro, over a mile wide, occupies the southern portion.

Zumbrota. In this town are still larger areas of the rolling surface characteristic of the upper Cambrian. The northwestern quarter of the town is high and simply undulating. The north branch of the Zumbro crosses the southern tier of sections.

Goodhue, in the western part, contains the line of the outrunning Trenton limestone, and is there a high table-land. The rest of the town is lower, and exhibits broad valleys and ridges. It contains no large streams, and is wholly arable. There is a little scattered timber in secs. 3, 10 and 11.

Featherston is intersected by the Hay creek valley on the east and by Spring creek valley on the west. These valleys are deep and wide, but their slopes are almost uniformly turfed, while between the bluffs that inclose them are some of the finest farms in a rich, deep loam. The higher farms, on the uplands between the valleys, are based on a yellowish loam for subsoil, and are fertile and reliable for the usual farm crops. Some of them are sightly, and command very picturesque landscapes, extending over the valleys with which the town is nearly surrounded. There is some oak and elm in the valleys, sufficient for domestic fuel. The whole township is undulating to rolling.

Burnside is much broken by hill and valley. There is a wide belt of bottom-land and terraced flats along the Cannon river and the Mississippi, much of which is timbered.

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* A magnificent view is afforded from the high land near the church, N. W. ¼ sec. 15, Welch. The mounds south from Hastings can be seen distinctly, also the smokes of Hastings and the high land above Hastings on each side of the St. Croix valley. From the high point in Burnside, secs. 16, 17 and 18, is visible another comprehensive landscape. The timbered region in secs. 7, 8, 17 and 18 is one uniform flat surface, of loam-covered drift. The timber is all young.

Red Wing and Wacouta. These are contiguous fractional townships lying on the Mississippi, made up of bluffs and bottom land pertaining to the near shore. They are hilly, but have a rich, fine clay soil even on the tops of the hills, formed by the loess loam. The bluffs at Red Wing rise, approximately. 350 feet above the Milwaukee depot.

Hay Creek has a deep valley running nearly east in the northern part, and another crossing the town in the centre east and west, with various branches. Wells creek also crosses the southeast corner of the town. These make a rolling and hilly surface for the whole town, the hills being from two to four hundred feet above the valleys. Yet owing to the abundant overspread of fine clay and loam, covering the old gorges in the rock, but little of it is not tillable. In some of the valleys are heavy forests, but usually the timber is confined to the slopes and is scattered aod rather small.

Belvidere has chiefly a northward surface drainage, by which various branches of Wells creek unite to introduce a hilly contour in the northern half of the town. The southern half, though much higher, is simply undulating or rolling. It has some timber in the northeastern corner, along Wells creek. On the eastern border of the town is an isolated mound of the Trenton-St. Peter sort, being the most eastern in the county, the elevation about twelve hundred feet above the sea.

Florence and *Central Point.* These towns border on lake Pepin, and are broken and hilly. There are several deep valleys which cross the town westwardly from lake Pepin. There is considerable peat in secs. 3 and 8, and probably in numerous other places.

Elevations. The greatest recorded elevation in Goodhue county is on the line of the Minnesota and Northwestern railroad, on sec. 23, Kenyon, being 1250 feet above the sea-level; but large areas of several other townships, notably Cherry Grove, Roscoe, Holden, Wanamingo, Leon and Belle Creek, would, if subjected to careful measurement, prove to have an equal elevation.

The following lists of elevations on the railroads that cross the county have been obtained from the offices of the chief engineers. These ascertained points furnish the data from which, by the aid of the pocket aneroid barometer carried in the survey of the county, the main topographic features are represented by the contour lines seen on the map accompanying this chapter.

Elevations on the Chicago, Milwaukee and St. Paul Railway.

	Miles from St. Paul.	Feet above the sea.
Etter,	28	689.84
Red Wing,	41	685.84
Frontenac,	52	719.34
Lake City,	68	703.84

From Mazeppa to Zumbrota.

	Miles from Midland Junction.	Feet above the sea.
Mazeppa,	51.2	935
Foaest Mills,	57.4	970
Snmmit (grade),	58.8	986
Zumbrota,	59	980

From Red Wing to Cannon Falls.

	Miles from Red Wing.	Feet above the sea.
Red Wing depot,	....	685.84
Cannon Falls Junction,	4	692
Crossing of slough (bot. 675), grade,	4.25	684
Cnt,	9.7	730

	Miles from Red Wing.	Feet above the sea.
Eagle Mill,	11.5	719
County line,	14.2	748
Cannon river (bot. 732), grade,	15.43	752
Cannon river (bot. 736), grade,	15.62	755
Summit,	18.3	821
Creek (bot. 771), grade,	18.6	817
Pine creek (bot. 766), grade,	19.4	780
Cannon Falls depot,	21.3	816.5

Elevations on the Wisconsin, Minnesota and Pacific railway.

From profiles in the office of engineer Hoffman, St. Paul.

	Miles from Waterville.	Feet above the sea.
Granville,	37.7	893
Chub creek (low water, 862; high water, 867), grade,	38.5	874
Line of Dakota and Goodhue counties,	43.6	841
Cannon river (water, 781), grade,	44.8	810
Cannon Falls depot,	45.1	814
Belle Creek depot,	55.7	707
Belle creek (bottom, 696), grade,	56.4	707
Spring creek (bottom, 670), grade,	63.1	690
Hay creek (bottom, 669), grade,	64.7	691
Crossing of Main street, Red Wing,	65.6	709
Red Wing depot,	65.8	706

Elevations on the Minnesota and Northwestern railroad.

From profiles in the office of H. Fernstrom, engineer, St. Paul.

	Miles from St. Paul.	Feet above the sea.
Randolph,	32.7	878
Chub creek (bottom, 862), grade,	32.9	876
Cannon river (bottom, 846), grade,	33.3	874
Summit, grade,	41.1	976
Spring Creek station,	41.3	969
Spring creek (bottom, 956), grade,	41.9	966
Summit, grade,	46.2	1186
Nerstrand,	46.4	1184
Depression, grade,	47.5	1147
Summit, grade,	49.4	1214
Zumbro river (bottom, 1071), grade,	52.6	1142
Kenyon,	53	1144
Summit, grade,	55.7	1250
North branch of Zumbro river (bottom, 1156), grade	60.5	1179
West Concord, Dodge county,	62.4	1232
Summit, grade,	63.6	1280
North middle branch of Zumbro river (bottom, 1174), grade,	67.7	1192
Summit, grade,	69.5	1251
Zumbro river (branch of, bottom, 1184), grade,	70.4	1228
Dodge Centre, Dodge county,	71.8	1296
Summit, grade,	79.1	1365
Hayfield, Dodge county,	80.9	1317
Cedar creek (bottom, 1286), grade,	83.0	1298
Summit, grade,	84.5	1342
Waltham, Mower county,	85.9	1325
Red Rock, Mower county,	90.7	1256

	Miles from St. Paul.	Feet above the sea.
Roberts creek (bottom, 1219), grade,	91.4	1243
Summit, grade,	92.2	1262
Crossing of the Southern Minnesota railway,	93.9	1230
Crossing of the Chicago, Milwaukee and St. Paul railway,	96.7	1213
Red Cedar river (bottom, 1178), grade,	97.3	1199
Austin, Mower county,	97.7	1197
Red Cedar river (bottom, 1169), grade,	98.2	1197
Rose creek (bottom, 1167), grade,	101.7	1191
Summit, grade,	103.2	1217
Varco, Mower county,	103.9	1205
Summit, grade,	105.4	1214
Depression, grade,	107.9	1192
Summit, grade,	108.9	1204
Lyle, Mower county,	109.1	1202
Crossing of the Chicago, Milwaukee and St. Paul railway,	109.2	1200
Mona, Mitchell county, Iowa,	110.5	1170

Elevations on the Rochester and Northern Minnesota railway.

	Miles from Winona.	Feet above the sea.
Pine Island,	65.86	998
Lena,	70.66	1073
Forest Mills,	73.14	1023
Zumbrota,	74.56	971

The city datum of Red Wing is 16.75 feet below the level of the rail at the Milwaukee depot—the extreme low water of 1859. Lake Pepin at ordinary low water is 662 feet above the sea.

The average elevation of the county, estimated from the contour lines, would be as follows: Central Point, 725 feet above the sea; Florence, 975; Wacouta, 925; Red Wing, 800; Hay Creek, 975; Belvidere, 1100; Burnside, 825; Featherston, 1000; Goodhue, 1100; Zumbrota, 1075; Pine Island, 1075; Welch, 925; Vasa, 975; Belle Creek, 1050; Minneola, 1075; Roscoe, 1125; Cannon Falls, 925; Leon, 1080; Wanamingo, 1150; Cherry Grove, 1200; Stanton, 925; Warsaw, 1050; Holden, 1150; Kenyon, 1210. These figures, considered in proportion to the areas they represent,* give an estimated average elevation for the county of about 1045 feet above the sea.

Soil and timber. The soil of Goodhue county is based on a clayey subsoil in all places except on the terrace-plains that skirt the main streams. This clay is generally fine and loamy; but in the high prairies of the western towns it is mingled with some pebbles, and even contains foreign boulders of a foot or more in diameter, being in that case the representative of the till-clay of one of the early glacial epochs. Yet, however frequent the stones on the surface, or in the immediate subsoil, the real soil, which sustains the

*Florence and Central Point are considered equal to one town, their areas being as 7 to 1; Wacouta, Red Wing and Burnside make another, their areas being as the figures 1, 2 and 8; Welch and Stanton together make two towns.

annual crops of the farmer, is invariably of a fine grain, and usually of a black color, with a thickness from a few inches to several feet. The stones in the subsoil which appear in the western part of the county, gradually disappear toward the east, and are wholly wanting in the extreme eastern part of the county. The subsoil clay, which in the western towns seems to be a true till at no great depth, passes through an intermediate, pebbly stage in the central part of the county, and is gradually replaced by the clay which is known as the loess-loam, referred to in reports on several counties. This fine, yellowish loam, which sometimes is a compact clay, constitutes the subsoil in the rolling towns of the eastern tiers.

The trees which grow native in Goodhue county consist in the main of black, burr and white oak, white and red elm, aspen, bass, white birch, white and black ash, maple, hackberry, butternut, bitternut, black walnut (in sec. 16 and in the Cannon valley in Burnside), black cherry, box elder, cottonwood, and a few scattering trees of white pine and red cedar.

THE GEOLOGICAL STRUCTURE.

The geological range of Goodhue county is very nearly the same as that of Wabasha and several others in the southeastern part of the state, but runs about a hundred feet higher in the lower Silurian strata. It also embraces the Cretaceous, which perhaps has a thickness of fifty feet in the county.

The St. Croix formation. This formation, although known as a sandstone, embraces several members which can easily be distinguished from each other over a wide extent of territory, and some of these distinctions are so general that they have been recognized in eastern Wisconsin.* It occupies the lower portion of the Mississippi bluffs, and extends several hundred feet below the river itself, having the following grand divisions, in descending order:

1. Sandstone, in some places containing green-sand and impure limerock in thin layers in its upper part. From this is obtained sand for making glass; the *Jordan sandstone*; about	90 feet.
2. Shaly, aluminous and calcareons layers, with some beds of sandstone and of green-sand; extending below the level of the river at Red Wing; this includes the St. Lawrence limestone; about	140 feet.
3. Micaceous and feldspathic sandrock, generally white, but often gray, with beds of shale; abont	85 feet.
4. Shale, bluish or greenish; abont	75 feet.
5. Siliceous sandrock; from 200 feet to	300 feet.
Total thickness,	690 feet.

*Geology of Wisconsin, 1873-77, vol. ii., p. 259.

The thickness given for the separate members is subject to considerable variation. The term *St. Croix* should not perhaps be extended so as to cover the siliceous sandrock (No. 5 of the section), since it is not in outcrop on the Mississippi river, nor on the St. Croix, where this term was applied at first. This sandstone (No. 5) seems to be the equivalent, in a general way, of the lighter-colored lake Superior sandstone. It is seen at Hinckley, in Minnesota, and in the gorge of the Kettle river.* It is the most probable representative of the Potsdam sandstone of New York. No. 1 is the same that has been denominated Madison sandstone by Prof. Irving, of the Wisconsin survey, but its thickness here seems to be more than twice that given by him. It embraces

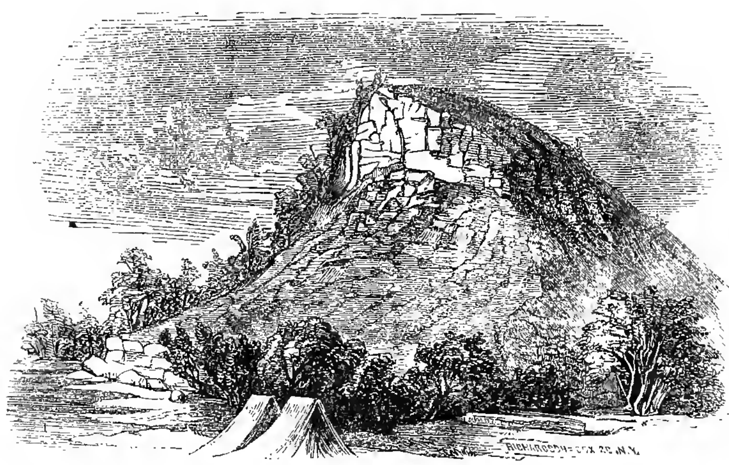

FIG. 2. LA GRANGE MOUNTAIN IN 1848—*Owen.*

Dr. Owen's "sixth trilobite bed." No. 2 embraces Owen's fifth, fourth and third trilobite beds, and covers the horizon which in Wisconsin has been described as Mendota limestone. It has been opened for building-stone on the east side of Pine street, in Red Wing. It is fossiliferous with trilobites and with brachiopods. La Grange mountain, now known as Barn bluff, has supplied many specimens of trilobites of different species from this member; and recently, within the streets of Red Wing, in opening the ground for sewers, this member afforded thin, brownish, calcareous layers, which seem to be lenticular within the shales and green-sand, and contain impressions of a large Orthis, and of other fossils.† No. 3 is a sandstone which is very nearly on the horizon of that quarried at Dresbach, in Winona county, and, like Nos. 4 and 5, is only known from the records of deep wells sunk in other places.

* Eleventh annual report, p. 125.

† Fourteenth annual report, p. 317.

From this formation within the Mississippi valley have been described a great many species of fossil remains. These include brachiopods, trilobites, graptolites and pterepods, as well as articulates, gasteropods and crinoidal stems.*

Brachiopods.

LINGULA (LINGULEPIS) PINNAFORMIS, On. In the siliceo-calcareous layers. St. Croix Falls. "Near the base of member b."

LINGULA ANTIQUA, Hall. Falls of the St. Croix.

LINGULA AMPLA, On. In the Lingula and Obolus grits, "member c." Dalles of the St. Croix. Hall says: "Lowest fossiliferous beds near Trempeleau;" not in the St. Croix valley.

LINGULA PRIMA, Con=ORBICULA PRIMA, On. With the preceding at the falls of the St. Croix.

OBOLUS APOLLINIS, Vern. "From member b, of the grits below Mountain island, nearly opposite the old mouth of Black river."

LINGULA WINONA, Hall. Lansing, Iowa, "more than 200 feet below the Lower Magnesian."

LINGULA MOSIA, Hall. La Grange mountain, with Dikelocephalus minnesotensis.

LINGULA AURORA, Hall. Mazomania, Wis., with Dikelocephalus minnesotensis.

LINGULA AURORA, *Var.* Hall. "Near the top of the sandstone series, and near the base of the Lower Magnesian limestone."

DISCINA (?) INUTILIS, Hall. Mazomania, Wis., with Dikelocephalus minnesotensis.

OBOLELLA (?) POLITA, Hall. "Lowest known fossiliferous beds of the formation, at Trempeleau, Black river, and other places."

ORTHIS PEPINA, Hall. "In light, buff-colored sandstone on lake Pepin, above Reed's Landing," Minniska and Osceola.

ORTHIS (LEPTÆNA) BARABUENSIS, Win. "Upper layers of the Potsdam sandstone, near the north end of Devil's lake, near Baraboo, Wis."

TRIPLESIA PRIMORDIALIS, Whit. Roche à cris bluff, Adams county, Wis.

ORTHIS, of an undetermined species, is mentioned in the "Potsdam sandstone" of Minnesota, by B. F. Shumard, in vol. i. (p. 627) of the Transactions of the St. Louis Academy.

ORTHIS REMNICHA, Winch. In lenticular, calcareous layers, about 125–150 feet below the limestone, at Red Wing.

ORTHIS SANDBERGI, Winch. In lenticular, calcareous layers, about 125–150 feet below the limestone, at Red Wing.

Trilobites.

DIKELOCEPHALUS MINNESOTENSIS, On. "In member d, ninety to one hundred feet below the base of the Lower Magnesian limestone, near the margin of lake St. Croix, above Stillwater; toward the base of La Grange mountain, and at the great slide, below lake Pepin." Fifth trilobite bed.

DIKELOCEPHALUS PEPINENSIS, On. "Near the base of La Grange mountain, top of member d."

DIKELOCEPHALUS (PTYCHASPIS) MINISCAENSIS, On. In soft grit-stones, third trilobite bed, 200–220 feet below the Lower Magnesian limestone, "near the mouth of Minniska river, at Mountain island and elsewhere, associated with Orthis and Lingula."

DIKELOCEPHALUS IOENSIS, On. "Near the mouth of Black river, more than 500 feet below the base of the Lower Magnesian limestone."

*On the palæontology of this formation in the Mississippi valley consult the following:
American Journal of Science and Arts, (2) xi. 187; (2) xxxvii. 226.
Owen's *Report of a geological survey of Wisconsin, Iowa and Minnesota.* Appendix.
Report of the superintendent of the geological survey of Wisconsin, 1861.
Sixteenth report of the New York state cabinet, 1863.
Geology of Wisconsin, vol. i., 1862.
Annual report on the Wisconsin geological survey, 1877, 1879.
Geology of Wisconsin, vol. iv.
Transactions of the St. Louis Academy of Science, vols i and ii.
Report on the geology of the lake Superior land district, 1851.
Fourteenth annual report on the Minnesota geological and natural history survey, 1885.

DIKELOCEPHALUS (PTYCHASPIS) GRANULOSUS, On. "Third trilobite bed, at the mouth of Miniska river, more than two hundred feet below the base of the Lower Magnesian."

LONCHOCEPHALUS CHIPPEWAENSIS, On. "In soft grit-stones of the Menomonie branch of the Chippewa," in Wisconsin; also in Marine Mill trilobite grit. Fourth trilobite bed.

LONCHOCEPHALUS (CONOCEPHALITES) HAMULUS, On. In the same beds as D. miniscaensis.

MENOCEPHALUS MINNESOTENSIS, On. One species, from the third trilobite bed, Minniska.

CREPICEPHALUS MINISCAENSIS, On. Third trilobite bed, Minniska.

CREPICEPHALUS (CONOCEPHALITES) WISCONSENSIS, On. Mountain island, and opposite the mouth of the Chippewa river, in Minnesota.

DIKELOCEPHALUS MINNESOTENSIS, *var.* LIMBATUS, Hall. With D. minnesotensis, at La Grange mountain.

DIKELOCEPHALUS SPINIGER, Hall. "At Trempaleau, near the middle of the formation."

DIKELOCEPHALUS MISA, Hall. "In the second fossiliferous beds at Trempaleau, and in the greenish sandstone near the same horizon at Miniska, about the middle of the formation."

DIKELOCEPHALUS OSCEOLA, Hall. "In the sandstone at Osceola mills."

CONOCEPHALITES MINOR, Shu. "Very common in the sandstone at Trempaleau."

CONOCEPHALITES EOS, Hall. "Sandstone at Trempaleau."

CONOCEPHALITES PERSEUS, Hall. "On the Mississippi opposite the mouth of the Chippewa."

CONOCEPHALITES SHUMARDI, Hall. Marine mills, and Kickapoo, Wis.

CONOCEPHALITES NASUTUS, Hall. "Gray and ferruginous sandstone at Kickapoo."

CONOCEPHALITES OWENI, Hall. "In myriads in certain layers at Marine mills."

CONOCEPHALITES ERYON, Hall. Trempeleau, and La Crosse, Wis.

CONOCEPHALITES ANATINUS, Hall. "In ferruginous sandstone above the lowest trilobite bed on the shores of lake Pepin."

CONOCEPHALITES PATERSONI, Hall. Associated with C. anatinus, "in a ferruginous sandstone at Trempaleau."

CONOCEPHALITES (?) BINODOSUS, Hall. "In sandstone at Osceola mills."

CONOCEPPALITES NACTUS, Hall. "Lower beds of the sandstone, near the mouth of Black river."

CONOCEPHALITES WINONA, Hall. Opposite the mouth of Black river.

CONOCEPHALITES IOWENSIS, Shu. (DIKELOCEPHALUS IOENSIS, On.). Mouth of Root river, Mountain island, and Trempeleau; also near the mouth of Black river.

CONOCEPHALITES DIADEMATUS, Hall. Marine mills, and "on the west side of the St. Croix river, about two miles below the falls."

ARIONELLUS BIPUNCTATUS, Shu. "Near the mouth of Lawrence creek, a tributary of the St. Croix river, Minnesota," and near the mouth of Root river, "about the middle of the sandstone."

CHARIOCEPHALUS WHITFIELDI, Hall. In greenish-gray sandstone at Trempeleau, and in some associated magnesian beds.

ILLÆNURUS QUADRATUS, Hall. Near Osceola mills.

TRIARTHRELLA AURORALIS, Hall. "Among the Dikelocephali at La Grange mountain."

AGNOSTUS JOSEPHA, Hall. Trempeleau, and mouth of Black river, "and elsewhere about lake Pepin."

AGNOSTUS PARILIS, Hall. On the shores of lake Pepin, in drab-colored sandstone, near the middle of the formation.

AGNOSTUS DISPARILIS, Hall. Friable sandstone at Osceola mills.

AGLASPIS BARRANDI, Hall. Near Minniska, Minn., and Mazomania, Wis.

PEMPHIGASPIS BULLATA, Hall. "Lower beds near Trempaleau."

AMPHION ? MATUTINA, Hall. "Lower beds near Trempaleau."

CONOCEPHALITES (?) (ARIONELLUS?) DORSALIS, Hall. "Lower beds near Trempaleau."

CONOCEPHALITES OPTATUS, Hall. "Lower beds near Trempaleau."

CONOCEPHALITES CALYMENOIDES, Whit. Eau Claire, Wis.

CONOCEPHALITES (?) QUADRATUS, Whit. Eau Claire and Ettrick, Wis.

CONOCEPHALITES (PTYCHASPIS?) EXPLANATUS, Whit. Hudson, Wis.

CREPICEPHALUS ONUSTUS, Whit. Eau Claire and Ettrick, Wis.

CREPICEPHALUS (?) GIBBSI, Whit. Berlin, Wis.

PTYCHASPIS STRIATA, Whit. Hudson, Wis.

PTYCHASPIS MINUTA, Whit. "Roberts' store, St. Croix county, Wis."

DIKELOCEPHALUS LODENSIS, Whit. Lodi, Wis.
AGRAULOS (BATHYURUS?) WOOSTERI, Whit. Eau Claire and Ettrick, Wis.
ARIONELLUS CONVEXUS, Whit. Ironton, Wis.
ELLIPSOCEPHALUS CURTUS, Whit. Hudson, Wis.
AGLASPIS EATONI, Whit. Lodi, Wis.
PTYCHASPIS BARABUENSIS, Win. "On the northern slope of the main ridge of quartzyte, at Devil's lake, Wis.

Graptolites.

GRAPTOLITHUS (DENDROGRAPTUS) HALLIANUS, Prout. Osceola mills, "in a thin seam of calcareo-aluminous shale, fifty feet above the water level."
Other graptolites occur in the "Mendota beds" at Central Point, in Goodhue county, not yet studied.

Pteropods.

THECA (HYOLITHES) PRIMORDIALIS, Hall. Trempeleau, Wis.
BELLEROPHON ANTIQUATUS, Whit. Osceola mills,

Gasteropods.

PALÆACMÆA IRVINGI, Whit. In quartzyte layers, in Jackson county, Wis.
PLATYCERAS PRIMORDIALIS, Hall. "Below the middle of the formation at Trempaleau, and on the Kickapoo river."
STRAPAROLLUS (OPHILETA) PRIMORDIALIS, Win. "On the north slope of the main ridge at Devil's lake, Wis."
EUOMPHALUS (?) VATICINUS, Hall. "Upper portion of the formation at La Grange mountain."
HOLOPEA SWEETI, Whit. Osceola mills.
PLEUROTOMARIA (?) ADVENA, Win. "North slope of the main quartzyte ridge at Devil's lake, Wis."

Articulates.

SERPULITES MURCHISONI, Hall. "In dolomitic beds of the sandstone at La Grange mountain."

Crinoids.

CRINOIDAL STEMS have been reported from the green sandstone at Hudson, Wis., and at Red Wing.

Worms.

ARENICOLITES WOODI, Whit. Baraboo, Wis.
SOOLITHUS is frequently reported from this formation.

This group of fossils indicates an upper primordial fauna, some of the species being continued into the limestone layers above, and all of them having a close alliance with the fauna of the so-called Quebec in eastern Canada and New York. Below these fossiliferous beds is a great sandstone stratum, seen in outcrop in north-central Minnesota, which has a strong lithological resemblance to the New York Potsdam, and also as sparse a fossil fauna. Below that are still other red shales and red sandstones, revealed by deep wells at Belle Plaine, Mankato, Hastings and East Minneapolis, having a thickness at least of several hundred feet. These red shales and sandstones become hard at last, and are then supposed to represent the red quartzytes seen in outcrop at New Ulm, and at Pipestone in the southwest part of the state, from which primordial fossils have lately been taken, and also the red quartzytes of Wauswaugoning bay and Pigeon point, in the northeastern part of the state.*

The Lower Magnesian limestone. There is a rather sudden transition from the formation just described, to this, causing nearly everywhere a marked change in the outward form of the bluffs that enclose the valleys. This forms a capping to the bluffs, and its face rises often perpendicular for a hundred feet. The thickness of this limestone, in some of the bluffs near the river, is often reduced to less than fifty feet. At Mr. Carlson's quarry, in Soren bluff, it is about forty-five feet, but at about forty rods further from the river it seems to have its normal thickness, which is over one hundred feet.

The lithological characters of this limestone have been given in reports on other counties. It is mainly a dolomitic, rather uniform mass of strata, which on being quarried are broken out in blocks of almost any desired size or thickness. Its upper surface is subject, apparently, to some irregularity, and seems to rise higher in some places than in others, the entire mass then being about fifty or sixty feet thicker. In Burnside the high bluffs of the Cannon which face southward are conspicuously separated into two belts, covering the horizon of this limestone. Outwardly they resemble the bluffs at Lanesboro, in Fillmore county, in which the New Richmond sandstone acts to produce a slope of non-exposure with two belts of exposed limestone, one above and one below.† In this case, however, there is no real sandstone that can be distinguished as such; but the appearance is due to the occurrence of two harder strata separated from each other about forty feet, producing more or less continuous shoulders of bare rock. This hardness is caused by much drusy, often amethystine, quartz and oölitic chert, and chert not oölitic, and by brecciated and conglomeritic belts, the whole making a curious rock, somewhat resembling the upper portion of the St. Lawrence as described in the report on Winona county. This firm and siliceous rock is in the shoulders that project, and between the shoulders the rock is more easily disintegrated, being broken by numerous joints, thin-bedded, rusty, oölitic or vesicular. This thickening of the Lower Magnesian limestone and the siliceous nature of these beds suggest, and seem to represent, the combined New Richmond and Shakopee; and this is still more probable since in other places the same hori-

* Thirteenth annual report, p. 70.

† Final report, vol. i., p. 288. In the first volume of this report this sandstone was erroneously identified with the Jordan of the Minnesota valley, which lies at a lower horizon.

zon exhibits a pure sandstone, as in the valley of Belle creek and at Cannon Falls. When thus augmented the thickness of this stratum of limestone is but little less than two hundred feet.

A few indistinct fossil forms have been found in this limestone at Red Wing, including a small trilobite, a small brachiopod, and some fucoid impressions. They will be specially described in the volume devoted to palaeontology.

The quarries at Red Wing are all in the Lower Magnesian limestone, and embrace the lower strata. Those at Frontenac are in about the same horizon, but give a stone that is finely and evenly vesicular.

The New Richmond sandstone. The sandstone which has been noted in other county reports, overlying the Lower Magnesian limestone, is also observable in Goodhue county. As has been stated already, there is a thickening of the Lower Magnesian in some places, due to the accession of layers at the top, this accession being characterized by very siliceous and cherty accumulations, giving that formation an apparent thickness of about two hundred feet. But this is due to the incorporation of the New Richmond beds and some part, if not the whole, of the Shakopee in the Lower Magnesian formation. Such a thickening is apparent in the Cannon river bluffs in Burnside, where there is visible no real sandstone, though much chert and free quartz. At Cannon Falls, however, in this horizon, may be seen about eight feet of white, crumbling sandstone. It is exposed in a short cut by the Midland railway, a few rods east of the depot. It is overlain by about twenty feet of Shakopee limestone. The sandstone is distinctly bedded, and seems to be in lenticular patches. It occurs again in a cutting for the highway, near the river, and also just above the dam in the banks of the Little Cannon, and at the bridge, S. E. ¼ sec. 3, Cannon Falls. The beds both of the sandrock and of the overlying limerock wave somewhat up and down, since at some places where the same horizon is exposed no sandrock is visible. Another good exposure of the New Richmond sandstone is near the tops of the bluffs at Nelson's mill, on Belle creek, sec. 16, Vasa.

At the falls of the Cannon, a short distance west of Cannon Falls, there is no sign of this sandstone, except in the existence of the falls themselves; the St. Peter comes exactly down on the Shakopee, showing a perpendicular wall of about thirty-five feet, and rising at the top so as to show the Trenton.

Along the junction of the St. Peter on the Shakopee is a horizon of vegetation and trees, the actual strata being hid from sight by moss and turf, and by calcareous tufa which is deposited by springs which issue at the bottom of the St. Peter. The Shakopee rises about twenty feet perpendicular from the water, below the falls. The water descends, by the falls, about four feet. There is a somewhat softer, shaly composition, and a slight tendency to underwear in the bluff, visible through a thickness of a foot or two above the high-water line, below the falls. This is probably due to this sandstone horizon, since the same strata continue to, and expose sandstone, at Cannon Falls.

The Shakopee limestone. There are but few points in Goodhue county where this limestone can be seen distinctly separable from the Lower Magnesian, and those have already been mentioned in describing the New Richmond and the Lower Magnesian. Its thickness in Goodhue county seems to be about twenty-five feet. The chief point of interest in connection with it is its evident fossil remains. These were first seen at Cannon Falls in 1876. They were found later at Oxford mills in the valley of the Little Cannon, at Tramm's limekiln, near Northfield, in Rice county, and lastly were seen in the projecting upper layers, more or less dislodged, by the roadside in sec. 15, Cannon Falls. The rock is, in these cases, almost made up of a congeries of casts, internal and external, of the forms of one or two species of gasteropods resembling a depressed Holopea, or a Pleurotomaria, about half an inch in diameter. At the Oxford mills this layer is about ten inches thick, and at Cannon Falls it is four or five feet from the top of the Shakopee. In some fallen pieces on sec. 11, Cannon Falls, were found a few forms of orthoceratites and of coiled shells. At Cannon Falls the Shakopee contains, near the Midland depot, numerous rounded masses, varying from a few inches to about two feet in diameter, some of them being coalescent, which are rudely hemispherical, the flattened side being downward. These are made up of thin concentric laminations, and outwardly resemble some of the stromatoporoids of the Devonian. They are probably some species of the new genus *Cryptozoon*, but apparently not *proliferum.** So far as can be seen, in nearly all places about Cannon Falls the Shakopee rises to within ten feet of the top of the highest gravel terrace, or about twenty feet above the Midland depot, *i. e.*, 834 feet above the sea.

*Thirty-sixth report of the New York state cabinet. By the kindness of Mr. W. H. Scofield, of Cannon Falls, a good collection of this fossil has been furnished the survey. It is described in the fourteenth annual report and named C. minnesotense.

The St. Peter sandstone presents the usual characters and seems to have, in the northern part of the county, a thickness of about 150 feet. At the Oxford mills a good measurement was made by aneroid, giving 145 feet, and at Cannon Falls 159 feet.

On sec. 33, Vasa, near White Rock post-office, is a small castle-like exposure of the St. Peter sandstone, which, being white against the timbered background, seen from the north is conspicuous for some distance, and must have given name to the post-office. It is on a shrubby and turfed knoll, a little to the north of the line of the Trenton, and has been kept uncovered largely by the north and west winds, which have a full broadside force across and up Belle creek valley. In some places this knoll shows a parti-colored variegation, some of the sandstone being of a light amethystine color.

The rocks of the Trenton period. Under this term will be described the rest of the strata found in this county, excepting those which belong to the Cretaceous. They have been divided in other county reports into several parts, and most of these parts are observable in this county. Whether any of these parts can be referred correctly to beds higher than the Trenton proper, so as to embrace the horizon of the Loraine shales of New York (or the Hudson River epoch), is still doubtful, though probable. The lowest portion of the Trenton rocks has been sometimes distinguished as *Lower Trenton*, but according to Mr. Ulrich the fossils contained in it show a mingling of Trenton and Chazy species.* This limestone appears in the tops of the bluffs at Cannon Falls where it shows a thickness of twelve or fifteen feet of layers that are workable for building stone. The rock is firm, rather close-grained, as limerock, but is injuriously affected by shaly partings and impurities. It is blue within, but generally exhibits a light, weathered dun color or drab. At the Oxford mill, sec. 25, Stanton, is a layer of two or three inches of combustible, slaty shale, like that seen in the Prairie creek valley in Rice county. †It is in the midst of hard layers of the lower Trenton. At Cannon Falls are several quarries, some of which also serve for lime-burning. From Cannon Falls southeastwardly this limestone is found extensively, forming the crest of the table-land which looks over the lower prairies of Belle creek valley, both from the east and from the west. It underlies immediately the prominently high lands in the southwest part of Featherston, the west part of Goodhue and

* Fourteenth annual report, p. 57.
† Final report. vol. i, p. 655.

the northwest part of Zumbrota townships. All along the Cannon river, west of Cannon Falls, it caps the prominent bluffs, jutting out from the bluffs of the Little Cannon in Stanton, Leon and Warsaw, but gradually coming nearer and nearer the level of the water in the stream, till, in the northeast part of Holden it disappears entirely beneath the floodplain, and below the water. It reappears on the Zumbro some distance above Wanamingo. It produces the same typographic features along this stream, as far east as it extends; but about Zumbrota the valley of the north branch of the Zumbro widens out, and the strike of this limestone runs further north and south from the immediate river. Between Wanamingo and Zumbrota several quarries are based on it, those about Wanamingo affording numerous large specimens of orthoceratites. It is also slightly exposed along the north-middle branch of the Zumbro at Pine Island, and thence westwardly to near the south-west part of Roscoe. It also caps the mound in secs. 13 and 24, Belvidere. At Pine Island it has supplied a specimen of *Lituites*.

Throughout the central and southwestern parts of the county this rock, of course, also exists, but it does not form the immediate surface. Its thickness at Pine Island is ten or eleven feet, but above this are two or three layers of similar rock, each about six inches thick, separated from the main mass, and from each other, by equal thicknesses of green shale. Throughout Zumbrota and Goodhue the line of the lower Trenton is not distinctly exposed by the topography. The high table-land to the west indicates, in general, the strike of the lower edge of the Trenton, but there are a good many sinuosities, and outliers that cannot be indicated, nor even known, owing to the heavy drift and loam which here is so situated as not to have come into contact with powerful erosive agencies.

The green shales, lying next higher, though having some firm limestone beds, especially in their lower portions, have an observed thickness, in the valley of the Little Cannon, of about one hundred feet, and this thickness can be taken as a fair average for the entire county where they exist. In their upper portions they are less argillaceous, embracing some thin beds of sand, and some beds that could not so correctly be designated shale as slate. They are also lighter colored. This shale can be seen with more or less distinctness, in innumerable places in the southwestern half of the county. Owing to its softness it is usually partly covered by superficial drift and loam. It acts a very important part in maintaining the surface waters within reach of the roots of vegetation. It causes many springs and marshes from which the upper sources of the Little Cannon, Belle creek, and of both branches of the Zumbro, derive an unfailing supply of water throughout the year. It is this bed of shale which gives the high prairies of this part of the county their greater amount of surface moisture, as seen in their numerous swales and bogs.

The upper Trenton beds of limestone have an indeterminate thickness in this county, not exceeding forty feet. They can be seen in several quarries in Leon, Wanamingo, Holden and Kenyon. Their lithology is similar to that of the lower Trenton, and they supply some of the best stone for building.

The distinctive *Galena* features also appear in some quarries in the same part of the county, but they include a thickness of rock, apparently of not more than twenty feet. For a description of the lithology of the Galena the reader may consult the report on Fillmore county, in vol. i.

The succession of parts, in the Trenton formation, is the same as in Fillmore county,* but the relative thickness of some of these parts is different. There has been found, however, in Goodhue county, no representative of the shale lying above the Galena, the equivalent of the Maquoketa shales of Iowa.

LOCAL DETAILS OF THE ROCKS OF THE TRENTON.

At Cannon Falls is presented the most favorable opportunity for examining the lower Trenton limestone, and the lower part of the green shales. The limestone forms the capping of the continuous bluffs and the isolated outliers that enclose the valley of the Cannon river, and of the Little Cannon, 140–150 feet in hight, all the way from the Rice county line to the town of Vasa. There are several quarries in the bluff next southeast of Cannon Falls village, long-wrought, covered by nothing but a very thin sheet of loam; and a few miles further southeast, notably at the farm of Mr. Parks, are frequent exposures of the green shales by the roadside, at levels somewhat higher in the strata than any that can be seen at Cannon Falls. From some of these localities fossils have been gathered in considerable quantity. The survey is greatly indebted to Mr. W. H. Scofield for aid in making collections of fossils about Cannon Falls.

Section of the Trenton in the valley of the Little Cannon.

On the S. E. ¼ of sec. 12, Holden, land of Sever Anderson, the bluffs of a tributary of the Little Cannon are abrupt, resembling those formed by the St. Peter sandstone, the rock having a slight dip north, causing the bluffs facing south to be dry. They are also parched by the southern sun, and blown by the southwest winds and kept bare. On the other side of the valley the bluffs are less abrupt, and are plowed from bottom to top and sown with wheat. Here the following section can be made out:

1.	Lower portion of the upper Trenton, shaly and shattered, weathered to a buff color, seen,	20 feet.
2.	Very shaly rock, but not shale, nor limestone, though calcareous, nor sandstone, though some of it is arenaceous; worthless and crumbling, - -	20 feet.
3.	Bluff-colored shale, with a few fossiliferous slabs, -	45 feet.
4.	Layers more durable, similar to those of No. 2, -	5 feet.
5.	Shale, like No. 3, - -	10 feet.

* Final report vol. i, p. 290. Compare the sixth annual report, p. 82.

6. Talus, covering some rock like Nos. 2 and 3, judging from the slope and the appearance of the bluff, and a heavy bed of green shale, the latter seen in outcrop a little further north by the roadside, near the center of the section, 50 feet.

Total exposure about 150 feet.

The horizon here included is about the same as that which in Fillmore county is almost entirely magnesio-calcareous, and is burned for quick-lime on Deer creek, northeast of Spring Valley. The change in the nature of the rock, between Fillmore and Goodhue counties, must be attribnted to a change in the ocean currents, or the depth of the Silurian ocean, between those points, the more rapid currents, or the shallower water, allowing the precipitation of only the coarser sediments.*

A little stone, of a poor quality, has been taken out of No. 1 here by Mr. Anderson.

The horizon of rock near Kenyon village falls into the upper portion of this section, and has furnished a number of Trenton fossils. Some of the layers here are coarse grained and yellowish, having some resemblance to the Galena. They contain large orthoceratites, species of *Lingula* and *Petraia.* These beds are seen along the creek at the west end of the village. In the banks of the Zumbro is seen a green shale with fossiliferous slabs, which more resembles the *green shales*, so-called, which lie next above the lower Trenton limestone.

On the S. E. ¼ of sec. 7, Kenyon, is a large quarry in rock which comes properly in the horizon of the upper Trenton. The rock is firm and blue on deep quarrying, but along the creek banks it crumbles into small pieces very much like the lower Trenton building stone at Minneapolis, the pieces being lenticnlar, of dirty-buff color, and rough. The shale (for it is argillaceous) is disseminated more evenly through the calcareous material than in the Minneapolis rock, but in the aggregate does not seem to differ much from it in quantity. There are here no layers of purely argillaceous, crumbling shale, like that at Kenyon village which lies below this rock. None of this rock is vesicular aud light buff, like the Mantorville Galena. In regular layers the thickness here exposed amounts to about 25 feet, and these probably fall into No. 1, of the section in the Little Cannon valley. A small church, and a farm-house near the quarry, have been bnilt from it. These show a blue color, with some faded and buff spots, and some iron-stains from pyrites.

There are small quarries in the lower Trenton in the N. W. ¼ of sec. 32, Warsaw, and in many places in Stanton. On sec. 19, Stanton, is a quarry owned by John Shantz. The beds aggregate six feet in thickness, and the layers are from four to eight iuches. They are blue at the centre, bnt mostly faded to a light drab. The beds are under about ten feet of loam, sand and stony gravel, many of the boulders being rotted. This is 135–140 feet above the surrounding flats of Prairie creek.

Near Fairpoint, in Cherry Grove, are quarries along the Zumbro, but those nearest are in Dodge county. They are in a light-colored, or buff, rock, in regular layers sometimes two feet thick (in deep quarrying), which weather into thin beds of an inch or less. They are less argillaceous than the rock at Kenyon, thongh not vesicular like the typical Galena. Of this stone have been built, at Fairpoint, houses belonging to Elisha Russell and Reading Woodard, and a small church.

Other quarries in the same stone, further down the Zumbro, in Goodhue county, are owned by George Devlin, who burns lime of an ashen-gray color on sec. 34, Cherry Grove, Edward Winston and O. Kam. There are also a great many other small openings in this rock as it is frequently exposed along the valley. These buff beds, amounting to about twenty-four feet, probably belong entirely above the section given from the Little Cannon valley, and must underlie the most of Kenyon.

The characters of the buff and vesicular Galena seem to fade out gradually, and to give place to the blue, or gray, calcareous beds of the upper Trenton, which in turn seem to take the characters of the lower Trenton at Minneapolis, the change taking place in going north.

At the crossing of the little creek, centre of sec. 27, Cherry Grove, near H. Linnemann's, the regular coarse and vesicular Galena appears. This is in a higher stratigraphical horizon than the rock at Devlin's.

On sec. 1, Cherry Grove, Arne Arneson and Andrew Everby have stone quarries. These are on a tributary of the north branch of the Zumbro. The rock here is in some of the gray beds of No. 1, of the section in the Little Cannon valley. They are compact, firm, and of light-blue color, weathering to a light buff; rarely exceeding four inches in thickness, exposed eighteen feet, of regular beds, with no shale.

On sec. 33, Wanamingo, Peter Oleson has a quarry in stone similar to the last; also Peter Peterson, near Oleson's. Elling Oleson has a fine large quarry opened in beds of the gray upper Trenton, on the ection line between secs. 8 and 9, Wanamingo. There is another equally fine on the opposite side of

* Vol. i, p. 300.

the road. These quarries reveal from 22 to 23 feet of fine building stone, in beds from three to eight inches thick. They show no shale, and no characters that pertain to the Galena.

There is a belt of wet and boggy land on each side of the river near Wanamingo, indicating the presence of the green shales between the upper and lower Trenton close under the surface. These belts are particularly noticeable where the road crosses the river between secs. 32 and 33, Wanamingo, although the lower Trenton is not there exposed.

On sec. 16, Minneola, the green shales are seen over a weathered exposure on the highway, four miles from Zumbrota, and afford characteristic fossils. In this weathered condition the shaly ingredients are mingled with the loam of the drift, and on the surface are to be seen also many white limy concretions which, while closely associated with the shale, yet owe their existence apparently to the loam.

The upper Trenton extends, as a green shale, and a shaly rock, nearly to Cannon Falls village. It can be seen frequently in sec. 20, Cannon Falls, as the road rises or falls over that horizon.

In Leon are the following quarries in the upper Trenton, gray beds, similar to those of No. 1, of the Little Cannon valley section, viz.: John Haggstrom and John Bank, sec. 9; Davis Miller, sec. 22, and Peter Swenson, sec. 23. The quarries of Swanty Anderson, sec. 20, and E. M. Edstrom, sec. 20, are more like the Galena, and probably are in higher beds than the last.

Near Zumbrota are the following quarries in the lower Trenton: P. P. Scott, sec. 14, Minneola, Erick Erickson, John Anderson, and Christopher Johnson, all on sec. 15, Minneola.

John Peterson, sec. 29, Roscoe, struck the Galena in a well and blasted out fragments. He has a quarry in the gray upper Trenton at a lower level.

John and Charles Peterson have a quarry in the bluff of the middle branch of the Zumbro, N. E. ¼ of sec. 32, Roscoe, in the gray beds of the upper Trenton.

Emanuel Andrist has a stone house, sec. 32, Roscoe, built of light buff stone like the Galena.

Anderson and Peterson have a stone quarry by the roadside, S. E. ¼ sec. 27, Roscoe, in the lowe Trenton. This lower Trenton is here from ten to twelve feet thick. J. Bringald has a quarry in the same beds near the last.

Jonn Chance and Peter Townsend own quarries in the lower Trenton in the bluffs northeast from the village of Pine Island.

There are doubtless many other quarries in the beds of the Trenton period in Goodhue county, but the foregoing are the most important, and will fully exemplify the formation to any person who takes the trouble to visit them. The out-running edge of the Galena seems to be characterized, in many places in Kenyon, Holden, Warsaw, Leon, Wanamingo and Cherry Grove, by a growth of forest trees.

The Cretaceous. In 1877 the first examination was made of the beds here to be described, but at that time no positive information could be obtained to show their Cretaceous age. The fact that they were used for the manufacture of a fine quality of stoneware, at Red Wing, and that they belonged to some formation between the Trenton and the loam of the glacial epoch, were strongly suggestive of their Cretaceous age. Since then the demonstration of their age has been complete. From some of the ferruginous sandstone beds have been taken angiospermous leaves which, according to Dr. Lesquereux, show the species *Salix proteæfolia.* Lesq., *Aralia* radiata, Lesq., and fragments of *Leguminosites*, *Ficus*, a new species of *Diospyros*, and several others too poor for identification.

The section of the strata is as follows:

Section in Cretaceous strata, sec. 3, Goodhue.

1. Loam and drift gravel, below becoming sandy, evidently the ruins of the St. Peter sandstone, - - - 14 feet.

[NOTE.—A rotting boulder of granite was seen at the bottom of this, and immediately upon the next.]

2.	Buff clay, but not the same as the loam,	6 in. to 1 foot.
3.	Cretaceous irony scales and concretions, and rusty sandstone in fragments,	6 in. to 1 foot.
4.	Potter's clay, fine and unctuous,	3 feet.
5.	Rusty sandstone, with fossil leaves,	2 feet.
6.	Potter's clay, same as No. 4,	1–2 feet.

The thickness of the parts varies in short distances, some of the beds tapering to points and wholly disappearing. At another point the exposed section was as follows:

1.	Loam,	10 feet.
2.	Cretaceous, made up mostly of the gray pottery clay, but having undulating beds of fine sand, and of coarse rusty sand. These undulating beds run out, and anastomose. Over the coarse sand is a continuous belt of iron-stone, or clay iron-stone, about three-fourths of an inch thick. Sometimes this branches and crosses the sand-bed. Sometimes the sand-bed is two feet in thickness. It narrows and widens as the clay widens and narrows. Seen,	10 feet.

A shaft, sunk below this exposed section, is reported to have shown ten feet more of alternating beds of potter's clay and sand-rock.

About the pit, in the debris, is seen every evidence of the Cretaceous, such as has been enumerated in counties further south and west,—irony scales and concretions, rusted sand-rock and conglomerate, fine clay-lumps in the white sand-rock, and finally the fossil leaves that resemble those seen at Mankato.

The crusts of iron and irony clay are abundant on the old refuse piles about the pits. Some of these, when fresh, have beautiful, nearly black, mammillated, upper surfaces, others have reticulated fine lines, or clusters of fine black crystals, strung in somewhat flowery or dendritic distribution over the surface of a much lighter color, or simulating a coralline growth. This distribution is due, however, to the fine cracking of the hard surface on which they are found, which may be compared to the sun-cracks in dried clay. The beaded black crystals run along the sides of a crack in a double row, or are aggregated all over it, making a linear agglomeration of reniform shapes more or less branching and reticulated. These lines are sometimes no larger than a thread of spool cotton. This is true, theoretically, wherever the seggregation first begins. They are sometimes a quarter of an inch thick, the original fissure in the crust being covered and re-cemented, and the surface generally overspread at considerable distance from the original crack.

It was found that this area of Cretaceous is quite extensive. It exists in the southwestern part of Featherston, and in the northwestern part of Belvidere. It is found in eastern Belle Creek and in the southwestern part of Cherry Grove. It probably underlies large areas in the central part of the county: but it is wholly impossible to define its boundaries with any exactness on account of the sheet of loam and drift clay which everywhere prevails. Some traces of the Cretaceous can be seen in the gravel of the Cannon river terraces, near the mouth of Hay creek, in the form of fragments of whitened chalcedony.

According to Mr. D. Hutcheson, sec. 32, Featherston, the pottery clay is found in several places over an area of a mile or so in secs. 32 and 31, from five to ten feet below the surface.

At Mr. Kraft's, near the head of Hay creek, S. E. ¼ sec. 33, Featherston, is a white spongy sandstone, at the creek level, with some parti-colored clays, which are probably Cretaceous, though poorly exposed. They lie lower than some layers of the Lower Magnesian on the opposite side of the creek.

On the N. W. ¼ of sec. 2, Goodhue, by the roadside, running S. W., is a small cut revealing the superposition of the Cretaceous over the Lower Magnesian, thus:

1.	Loam,	3 feet.
2.	Rusty sand, more or less white,	2 feet.
3.	Clay, not continuous,	6 inches.
4.	Broken-down Lower Magnesian,	2–4 feet.

This is very similar to sections in Blue Earth county, except that the Lower Magnesian is much broken and open. It is not coated with an iron-scale, but there is much irony matter — scales, lumps, and rusted rock, and even rusted pebbly conglomerate in the ravine adjacent.

The Cretaceous conglomerate occurs in loose pieces on the S. E. ¼ of sec. 12, Goodhue.

Mr. James Casey, sec. 26, Belle Creek, struck the Cretaceous clay and conglomerate on his farm, twenty-six feet below the surface, in a well, the conglomerate lying over the clay. It is also known on John Lally's farm, sec. 10, Belle Creek, according to Col. William Colvill,— where it is said to consist of a thick bed of white clay.

The high tract in eastern Goodhue and southwestern Belvidere, rising 1150 feet above the sea, seems to be underlain by the Cretaceous. The Cretaceous conglomerate is in place in the east-and-west road between secs. 11 and 12, Goodhue, near the school-house.

On the S. W. ¼, sec. 10, Belvidere, where the highway descends to the valley of a branch of Wells creek, there is a curious deposit, showing a thickness of about ten feet. It may be the very bottom of the Cretaceous. It is mainly sand, but contains a great many iron-scales, much chert, evidently derived from the wearing down of the Cambrian, some conglomerate of rounded quartz pebbles, some lumps of white clay, and some indistinct thin sheets of fine, nearly white, clay, the whole being very indistinctly bedded. Were not the Cretaceous known to be in this part of the county in considerable force, this could be referred to a "local drift" accumulation, and such may have been so referred in other cases.

At Zumbrota, and westward toward Wanamingo, are frequent traces of the Cretaceous in the materials of the drift, in the form of irony, concretionary balls, small pieces of lignite, and fragments of an iridescent shell, too small to be identified.

Northward from Fairpoint, in Cherry Grove, there is a blue clay which is struck in wells, and is believed to belong to the Cretaceous.

Along the road half a mile east of Fairpoint are unmistakable evidences of the Cretaceous, in the form of cemented, rusty conglomerate, in large lumps, hauled from the adjoining fields. These may be seen also at the bridge over the little creek, at Devlin's quarry, where they show a distinct and uniform stratification.

More minute search for this formation might disclose the Cretaceous much more general in Goodhue county than is yet supposed. There is some reason to refer the irony scales and irregular lumps of impure limonite which are found extensively on the summits of the bluffs in the eastern part of the county, and in counties southeast of this, to a residuum from the Cretaceous, the sand and clay having been washed out by the forces of the drift waters.

THE DRIFT.

Till. Probably three-fourths of the county, especially the uplands, can be said to be covered by the stony clay known as till. It is of a gray or blue color, and embraces the usual abundance of granite boulders. In Minneola and in southwestern Zumbrota, as well as about Wanamingo, the boulders are predominatingly, or very noticeably, referable to the igneous and metamorphic rocks about lake Superior. The color, as well as the composition, of this stony clay is certainly due largely to the admixture of debris from the Cretaceous, which, before the drift-period, must have covered the whole county. Though this till in many places exhibits its typical character, yet it shows variations, and some exceptional features. It shades into a clay which can hardly be referred to the same agency, and by the loss of its clayey constituents, it becomes simply a dirty, gravelly and stony stratum. There are some places, particularly along the main drainage valleys, where the till does not exist, though it would reasonably be expected, and instead of it is found this modified drift. Sometimes the underlying rock is rotted down *in situ*, and not glaciated. Such may be seen at Fairpoint. Here a thickness of three or four feet of pieces of the rock, hardly removed from their original position, lie just under the loam, and are mingled with the drift over the more firm beds of the quarry. This till, wherever it exists as such, shows the greater age of the earlier glacial epoch. It is faded by hydration to a greater depth, and it exhibits irregularities in position and character which must be referred to the vicissitudes of a longer history.

Pebbly clay. In particular, this till bears some relation, not yet fully ascertained, to a loamy clay containing pebbles and a few boulders. In Vasa township, on both sides of Belle creek, this pebbly clay can be seen. It also bears, at this place, occasional boulders of large size. It is of the color of the loam, in general, to the depth of several feet, but, though resembling the loam in composition, it is light-blue at some greater depth. This is in the highest land in this part of the county, and is covered by the usual stoneless loam. Whether it exists in the valleys is not known, since the overlying loam forms an effectual screen. Large stones from this deposit are seen occasionally on the brows of the bluffs, and rolled down the slopes onto the tilled soils of the valleys. These stones are frequently of northeastern origin. At Pine Island, over the quarry of Chance and Townsend, is a loam that becomes gravelly, and sparingly embraces large boulders. This clay is quite different from a glacier-produced till. Yet it is not easy to account for the presence of pebbles and occasional stones without the aid of ice. It seems to bear the same relation to the true till of the earlier glacial epoch that some pebbly clays do to that of the last.*

There are traces of the till-sheet as far east as the Mississippi river at Red Wing, and sand and stones are to be seen even at Central Point. Between Lake City and Frontenac the upper slope, extending from the uppermost terrace to the bluffs, is often seen to consist of till with large boulders. It is, still, generally covered with the loam of the country, and mixed with it, having the same color. It apparently runs below the high gravel terrace of the Mississippi. There is a considerable drift-clay within the bluffs back of Florence, and large

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* Final report, vol. i, pp. 544, 659.

northern boulders; also up the valley west of Florence, containing Cretaceous iron-scales.

Loess-Loam. This is found throughout the county. It forms the soil, and also the subsoil. It varies in thickness on the uplands from a foot or two to twenty or thirty feet. Its greatest thickness is in the eastern and northeastern part of the county in some of the old valleys. It is generally homogeneous and massive, but shows a horizontal lamination along the Mississippi river and in the principal valleys. It is yellowish, or earthy-yellow, except at considerable depth, where it becomes dark, or bluish-black. The terra-cotta clay formerly used at Red Wing came from the blue interior of the terrace which accompanies Hay creek, and upwardly passes gradually into the surface loam. Below it is laminated. In some places this loam becomes superficially sandy. This is the case in the northern part of Welch, and in the valley descending to Etter. It also becomes pebbly, and in rare cases it can hardly be distinguished from the pebbly condition of the till above described.

The loess-loam, in this county can be referred to the drift forces for its origin, with more certainty than in some other counties that have been described. While it is everywhere present, and often is laminated, in favorable situations, it does not lie, generally, on the disintegrated rock with no intervening drift clay or gravel. It came upon the county probably from the northward and westward at different epochs, and its transporting agent was probably very cold water. It seems that this water, in its slow movement, bore along, at some of its stages, more or less mud and gravel-laden ice, thus producing pebbly, or stony, clays which resemble the loam in some places, and change horizontally into it, and the till-clay in others. This clay-producing stage in Goodhue county must have been near the acme of the cold period, when the waters were so abundant as to cover the uplands of the county.

Boulders. The large, often conspicuous, boulders that are seen in nearly all parts of the county, are to be referred either to the earlier till-sheet, or to the extension of the same over areas where the depositing agent seems to have been water rather than glacier-ice. When seen on the prairies, as in Kenyon and Cherry Grove, they are seldom glaciated, but show long-weathered surfaces, rough and stained. They are mostly of granite, and are often very large; one of flesh-red granite was seen in sec. 29, Belle Creek, measuring twenty-six paces in circumference, and rising nine feet above the ground. Another was noted about half a mile northwest of Kenyon. This is twelve feet in diameter, and about seven feet in hight. They are abundant in shallow drainage valleys, in the high prairies, where the loam has been carried out and left the old drift-surface more or less bare. They are sometimes seen under eight or ten feet of fine loam, in cuts by the roadside, and show that they were weathered so as to lose their glaciated exterior before they were covered by the loam. Often large boulders of granite lie on the St. Peter outliers, in the Cannon valley in Stanton. Traveling along the state road from Red Wing to Marysville in Dakota county, the first boulders appear between secs. 8 and 17, in Welch.

A great many boulders from the igneous rocks of the Cupriferous formation about lake Superior may be seen at Zumbrota and thence to Wanamingo, including amygdaloidal rock, porphyry with flesh-red crystals, doleryte and occasionally a piece of native copper—of which last a piece weighing four or five pounds was found at Zumbrota in grading the streets.*

Gravel plains and terraces. The position of Goodhue county with reference to the marginal action of the ice, and of the waters issuing from it, at the date of the last glacial epoch, was favorable for the accumulation, within its area, of much of the gravel and sand which was disengaged from the ice and carried forward to lower levels by the turbulent waters. The valley of the Cannon river was flooded permanently, during the continuance of this cold epoch, with waters that came directly from the ice-fields of Dakota and Rice counties, and which bore along great quantities of floating ice and of mingled mud, sand and gravel. The Mississippi was also at its flood-stage. These valleys were filled with alluvial detritus to the hight of their highest terrace, and flowed at a permanent level about one hundred and twenty-five to one hundred and fifty feet higher than now, the bottom of the water being determined by this terrace. On the withdrawal of the ice-field further north, and the cessation of the supply of such detritus, these streams began to excavate their present channels in the loose materials over which they had been flowing. This excavation was a process of short duration, and continued as long as any glacial condition of the preceding cold epoch lingered in the state. When the rivers were reduced to more nearly their present stage, a slow process of re-filling seems to have been begun which we see going on at present. This re-filling is most evident

* Other small pieces are reported to have been found on the N. W. ¼ of sec. 20, Cannon Falls.

in the lower portions of the river valleys, and in those parts where the valley is much larger than is now required by the stream flowing there.

Wherever there are alluvial terraces of this nature bordering the streams of the county this history seems to have been enacted. It is most evident along those that have their sources far enough west to have drained the margin of the ice-field. Hence the Cannon river and Prairie creek, in the northwestern part of the county, exhibit these features most markedly. To some extent also the north branch of the Zumbro shows the same.

The *Stanton flats*, which are only the lateral extension of the gravel terrace of the Cannon and of Prairie creek over several square miles in Stanton township, the wide gravel flats and the terraces of the Cannon, at Cannon Falls, the beautiful exhibition of terrace levels at the mouth of the Cannon, in Burnside, and thence to Red Wing, the upper flat on which the Milwaukee railroad is built from Wacouta to Frontenac, and the high terrace about the mouth of Wells creek, are illustrations of this formerly flooded stage of these rivers.

There are two terrace-flats along these main streams which can nearly always be seen. One is but little more than one hundred feet above the present water-level, and the other seems to average about fifty feet.

All the way from the west line of the county to Cannon Falls the gravel of this deposit lies on the Shakopee limestone, and rises from forty to fifty feet above it. The upper surface of the Shakopee, however, a short distance above Cannon Falls, has produced its own terrace, from fifteen to twenty feet lower, though still much obscured by gravel from the same deposit, introducing some irregularity and confusion. The high gravelly terrace, however, is constant. As it descends toward the east, and passes over the strike of the Shakopee at Cannon Falls, the Shakopee continues to be evident as a higher terrace, and the roads running over it become more affected by the sand resulting from the disintegration of the St. Peter sandstone. The effect of the Richmond sandstone is seen in the knobby remains of the Shakopee, rising above the upper surface of the Lower Magnesian terrace, still further east. On sec. 2, Cannon Falls, the flood-plain of the river is 167 feet below the top of the Shakopee. Some aneroid measurements gave the following results for these terraces at Cannon Falls, viz.. The flood-plain above the river, eight feet; the terrace on which the school-house stands (south side), above the flood-plain, thirty-one feet; the terrace on which the Episcopal church stands, above the school-house flat, twenty-six feet; the top of the bluff containing the Trenton, above the terrace of the Episcopal church, one hundred and sixty feet. There seems to be here two terraces due wholly to alluvial agency, one being thirty-one feet above the flood-plain and the other fifty-seven.

The highest gravel terrace, about two miles west of Cannon Falls, is, by aneroid measurement, sixty-two feet above the top of the exposed Shakopee at Cannon Falls, and below it are four terrace-flats which descend by the following intervals: 29 ft., 13 ft., 12 ft., 8 ft., 30 ft. to the river. There is a trace of loam, higher than this highest terrace, making a blind shoulder on the slopes of the St. Peter, some miles up the Little Cannon valley, and other tributaries of the Cannon, which, when cut by the grading of streets, shows a pure loam, rather clayey, making good farms. At other places it seems to be a hardpan clay, or till, with loam.

This display of terraces is visible on both sides of the river, and is unprecedented in the state. This whole system is disturbed here, and perhaps some of these benches are caused, by the Shakopee limestone and Jordan sandstone which rise higher and higher above the river, in going east from the county line. The uppermost terrace-flat is slightly uneven in its elevation above the river, which seems to average about ninety feet. It is probably the continuation of the highest terrace of the Cannon described in Rice county,* and has about the same hight above the river as at Northfield.

On sec. 29, Burnside, this upper terrace is very marked and rises to one hundred and ten feet above the low-water stage of the river. On sec. 22, of the same township, where the flood-plain of the Cannon has the same hight as that of the Mississippi, it rises one hundred and thirteen feet above the flood-plain, and it is divided into two parts, the lower flat being that on which are seen many prehistoric artificial mounds, thirty-eight feet above the same flood-plain. Very large mounds are found also further west, on the higher flat.

At the mouth of the Cannon river, or rather at the union of the Cannon valley with that of the Mississippi, secs. 21, 22 and 26, these terraces exhibit a surprising development. The level of the upper flat extends up Spring creek valley, constituting the main portion of the tilled area of that valley. The same is true of the Belle creek valley as well as that of Hay creek. In the case of Hay creek the same deposit apparently continues through the old dry channel which unites that valley with that of Wells creek, through Hay Creek township, and thence down Wells creek to the Mississippi near Frontenac, where it is about one hundred and thirteen feet above the level of lake Pepin. The greater power of the waters of the Cannon river in producing this terrace is evident not only in the greater hight it has wherever that stream had unhindered action in building it up, but in the position of the individual fragments of shaly or slaty rock disseminated through it. Even within the Mississippi valley near the mouth of Hay creek, the thin fragments of rock, of whatever nature, revealed in a fresh cut by the grade of the Midland railroad, lying loosely amongst finer gravel, slope invariably toward the west-northwest, i. e., toward the flowing water of the Cannon rather than that of the Mississippi.

At Red Wing there are traces of a terrace of gravelly composition, which rises about one hundred and thirteen feet above the lake. Such can be seen in recent grading in the northern face of "University hill," which rises about two hundred feet above the Milwaukee depot; though the hill itself, except the copious over-spreading of stony clay and loam, consists of the St. Croix formation, and debris from it. This hight, however, is not everywhere maintained between the mouth of the Cannon and Red Wing, nor at Red Wing. Instead, there is a terrace-flat which has a hight of about seventy-seven feet above the lake, and on this the main part of the city of Red Wing is built; though its limits extend further up the ravines and upon some of the higher bluffs. Near the depot of the Chicago, Milwaukee and St. Paul railway the following section of this terrace was taken:

Section in the river-terrace at Red Wing.

1.	Yellowish loam-clay, making red brick, seen	20 feet.
2.	Yellowish sand, fine, horizontally laminated,	3 feet.
3.	Gravel and sand (from N. E.), coarse, somewhat clayey, the lowest exposed part being cemented into a loose crag; this brings the section down to the level of the depot,	20 feet.

No. 1, of the foregoing section, falls down and mingles with the gravel of No. 3, and the mixture presents a very deceptive resemblance to till.

On sec. 23, Red Wing, at the residence of Col. Wm. Colvill, this terrace rises about seventy-seven feet above the lake. It is overspread with loam generally, but its lack of continuity, and its somewhat uneven upper surface, as well as the occurrence of numerous stones and a few large boulders, indicate that it is not wholly of alluvial origin, but contains a considerable amount of till.

At Frontenac the terrace near the lake, on which the old village stands, is fifty-eight feet above lake Pepin; but there is another terrace-flat, on which the Episcopal church stands, which, by aneroid, is eighty-eight feet above the lake. Frontenac station, likewise on a terrace-flat over two miles in width, is fifty-five feet above lake Pepin. But immediately south of the station begins a higher terrace rising more than one hundred feet above the lake. Still further south, and near Wells creek, is the highest terrace-flat, supposed to be due to the action of Wells creek when it received waters from the Cannon through the old Hay creek valley. This probably is contemporary with the hundred-foot terrace near Frontenac station, and shows a local increase of hight due to the rapid supply of material at the mouth of Wells creek, the same as noted at the mouth of the Cannon.†

Wells. Vegetable remains in the drift. The foregoing statements respecting the nature of the drift are based largely on facts derived from common wells. The most of these observations, however, were not recorded in detail. Some of the most important facts noted were the following:

* Final report, vol. i, p. 664.

† The principle here illustrated is the same as that involved in the discussion of the origin of lake Pepin — viz., the filling up of the bed of the main valley by a turbulent tributary stream.

The well of Mr. Philo Brown, sec. 16, Burnside, passed into twenty-two feet of yellow loam, with not even a pebble to be seen, without going through it. His neighbors have the same, or similar experience. This location is on the point of a long high ridge, considerably within the valley of the Mississippi, about three hundred and fifty feet above its present level, well situated both for the reception of the full thickness of the loam, on the uplands, and for the loss of it by local drainage and wash since its deposition.

In Leon, Mr. W. H. Scofield has given the following particulars concerning a well situated near the summit of the divide between Belle creek and the Little Cannon, but on the east slope, about a mile from Belle creek on "east high prairie." After passing through black soil, three feet, red clay, eighteen feet, blue clay, three feet, and black muck, three feet, a large blue boulder was encountered, which was surrounded with something resembling grape vines. There was "quite a quantity of this material." Below this boulder was red clay, down to the limerock, twenty-four feet. The foregoing designations are by the party who owns the well.

At Zumbrota pieces of wood were encountered in a pebbly blue clay at the depth of thirteen feet. Indeed almost every well dug comes upon more or less wood, if it penetrates the blue clay to any depth. This gravelly blue clay was also met in wells in sec. 6, Zumbrota.

At Aspelund, in Wanamingo, a similar blue clay is found under the loam, in nearly all wells. This is on the high prairie level of that part of the county.

On sec. 2, Wanamingo, on the high prairie, land of William Boulett, a log of what appeared to be hemlock, or coarse pine, was found in digging a well, at the depth of twenty-six feet below the surface. This was embraced in a bluish-black clay, apparently a soil, and was five or six inches in diameter. It was covered with a hard, gravelly, yellowish clay, and by the loam that covers that part of the county.

In the valley of the creek, sec. 5, Belvidere, land of John Holtz, was found wood twenty feet under the surface, in the gravelly blue clay, or under it.

In Belvidere, S. E. ¼ of sec. 17, in a well belonging to Harold Knutson, a stick of wood three or four inches in diameter was found at a depth of forty feet below the surface. This was in a pebbly blue clay. Several others in the same vicinity have also found wood in digging common wells. These wells are on high prairie land.

A log as large as a man's body was found forty-seven feet below the surface in a well owned by N. Guild, on the S. E. ¼ of sec. 36, Goodhue.

Numerous other instances of vegetable remains being found at considerable depth below the surface, in the central part of the county, were also learned of but cannot be referred to definitely.

The artesian wells at Red Wing.

The first deep well drilled is at the depot of the Chicago, Milwaukee and St. Paul railway, beginning at the grade line of the road, six hundred and eighty-seven feet above the sea. The work was done by Mr. W. E. Swan, of McGregor, Iowa, who estimates the discharge at the surface at eight hundred gallons per minute. The water will rise seventy-five feet above the surface, when confined in a pipe. The water began to flow over at one hundred and ninety feet from the surface, and kept on increasing to the end.* Another deep well is situated about eighty rods west of the Milwaukee depot, three rods south of the track and thirty feet above it, and spouts three hundred barrels per day, rising thirty feet above the surface. This well passed through one hundred and sixty feet of drift materials, and entered the sandrock one hundred feet. Following is the record of the well at the Milwaukee depot, as given by Mr. Swan:

* Mr. Swan states that he stopped drilling at the red sandrock, in which he has no faith in ever getting water in any increased amount.

1.	Sand and gravel,	40 feet.
2.	Sandy shale,	10 feet.
3.	Blue shale,	50 feet.
4.	Sandrock,	10 feet.
5.	Blue shale,	30 feet.
6.	Mixture of sand, quartz and limestone,	45 feet.
7.	Soft sandrock,*	265 feet.
	Total depth,	450 feet.

In the early part of 1887, Mr. August Peterson obtained another artesian flow at the extreme N. W. corner of sec. 26, T. 113, R. 15, in the valley of Spring creek. The surface of the ground where this well begins is about fifty feet higher than at the well at the depot, above noted, and the water rises freely through a pipe that stands twenty feet above the surface. It is estimated that it would overflow at forty feet above the surface. On striking the sandrock (No. 5) the water rose to within twenty-five feet of the surface, and increased constantly in force and volume as the well was sunk deeper. The bottom of this well is one hundred and forty-six feet short of the bottom of the well at the depot. The water is soft, and pure, similar to that of the second well above noted. The well at the depot deposits a considerable irony sediment. The record of this well, as well as the foregoing facts, was furnished by Col. Wm. Colvill, and is as follows:

1.	Sand and gravel,	112 feet.
2.	Compact sandrock,	4 feet.
3.	Blue sandrock,	30 feet.
4.	Green, slaty shale,	90 feet.
5.	Yellow, green and brown sandrock,	15 feet.
6.	White sandrock,	104 feet.
	Total depth,	355 feet.

MATERIAL RESOURCES.

While Goodhue county will always remain pre-eminently an agricultural one, yet it has several other sources of material wealth besides those that spring directly from the soil. The water-powers of the county have already been enumerated. These, with several mills run by steam-power, give occupation and revenue to a large number of men, and bring into immediate and direct results the labor of the husbandmen, creating a supplementary industry without which the cultivation of the farm would be unremunerative and discouraging.

Building-stone. Goodhue county is abundantly supplied with this important article, and from some of the quarries a large amount is sent to other

* This is said by Col. William Colvill to have been coarse, and even conglomeritic near the bottom of the well.

counties, and to other parts of the northwest. The quarries in the Trenton formation have already been noted in giving the description of that limestone. The most important, however, are in the Lower Magnesian limestone, and are located at Frontenac and Red Wing.

The quarries at Frontenac are owned by the Frontenac stone company. The stone that is handled by this company does not all come from the same quarry though from the same general locality. Similar stone can be obtained throughout an area of several miles in adjacent parts of Goodhue and Wabasha counties. The quarry at present wrought is near lake Pepin, but formerly stone was obtained about two and a half miles south of Frontenac. The stone when sawed and dressed is delivered on board the cars at forty cents per superficial foot. This price is "for what you see in the wall," but the price varies according to the amount and style of work—even to two dollars per foot for fancy work. This stone is light-buff, evenly and finely vesicular, in heavy beds of five feet and less, and is so uniformly grained and massive that it is used indiscriminately either on edge or on bed. For particulars concerning the quality of this stone, and of that of Red Wing, the reader is referred to the chapter on building-stones, in the first volume of the final report. The section exposed at the quarry in the bluff near Frontenac is as follows, in descending order:

1.	From the top of the bluff to the top of the exposed rock,	44 feet.
2.	Rough, nodular, coarsely vesicular rock, not all seen,	46 feet.
3.	Quarried strata,	20 feet.

This quarry is near the bottom of the formation. A sample of this stone, cut from one block, fashioned as a baptismal font, about three feet and a half in hight, was exhibited at the late New Orleans Industrial and Cotton Centennial Exposition.

At Red Wing are several important quarries in the upper part of the bluffs. The principal owners are G. A. Carlson, R. L. Berglund and —— Danielson. They all quarry about the same horizon of strata, near the bottom of the limestone, and the product of the quarries does not differ greatly, one from the other. Much of it is burned for quicklime. At Red Wing several important buildings have been constructed of this stone, and it has been, to some extent, used in St. Paul and Minneapolis. The stone in the Catholic church at Red Wing came from Mr. Berglund's quarry. That in the Episcopal church is from Mr. Carlson's in Sorin bluff. The basement story in the Red

Wing and Diamond flouring mills is built of Red Wing stone. Other quarries of less importance, but supplying a local demand, are found in Belvidere, Hay Creek, Featherston and Vasa.

Quicklime. There is probably more quicklime sold from Red Wing than from any other point in Minnesota. The lime is well known for its excellence, and its strength. It is a magnesian lime, and hence sets slowly. It has but a small per cent of insoluble ingredients, and competes successfully in the markets of the state with limes from some of the upper Silurian strata of Illinois or the Devonian of Iowa.

In 1879 the following firms were engaged in this business, and producing the amounts expressed:

R. L. Berglund, two hundred and fifty barrels per week.

Danielson and Betcher, sixty to seventy barrels per day.

G. A. Carlson, ninety barrels per day.

Oleson and company, one hundred and forty barrels per day.

In 1885 G. A. Carlson made, from April 1st to Dec. 1st, seven hundred barrels per day. He has five constant kilns, but had only four of them running. The average price is about forty cents per barrel, on the cars. Mr. Berglund, in the same time, made about one hundred and twenty barrels per day.

At Cannon Falls a stronger lime is made from the Trenton limestone — that is, one that is more caustic, and quicker to slake and to set, evolving more heat. This lime has locally acquired a bad reputation, and masons are opposed to its use. It is said to make a good and strong cement in a stone wall, even adhering so firmly that the mass seems to be one, but in common plastering and ceiling it does not succeed. The "clinchers" drop off, and the walls soon fall down. This is all due probably to improper treatment by the mason. The lime being pure, and "short," so to speak, sets soon after being put on the lath. If the mason presses and smooths it further, so as to disturb the setting, it does not set again so strongly, and a little jarring causes it to fall off. It is not like the lime most used in this country, derived from magnesian limestone, which sets slowly, and to which probably most masons are accustomed. It is used successfully in stone walls because there the mason has no desire to move the mortar after it has been roughly applied. Wherever the Trenton is used for quicklime, the same difference will be found between it and the Red Wing lime.

Sand for mortar is abundant wherever access can be had to the gravel terraces, or the plains, that have been described along the principal streams; but in the absence of that, resort can be had to the St. Peter sandstone which can be easily excavated for the purpose. Such use is made of this rock on the S. W. ¼ of sec. 23, Goodhue. There are some townships, however, in the southwestern part of the county, in which sand for mortar has to be hauled a great distance, the whole country being uniformly covered with a clayey loam.

Brick of excellent quality are made at numerous points. The product of the yards at Red Wing is well known. The Capitol at St. Paul is made of red pressed brick from Red Wing. The following brick yards were noted in the survey of the county:

Brink, Williams and company, Red Wing, dark red brick.
Ole Simmons, Red Wing, red pressed brick.
William Lutz, Central Point, red brick.
H. S. Perkins, Pine Island, red brick.
L. D. Hart, Pine Island, red brick.
William Ward, one mile south of Zumbrota, dark red brick.
At several other places brick have been made to supply a temporary local demand.

Stoneware. At Red Wing are extensive establishments for the making of stoneware. The clay used is obtained in sec. 3, Goodhue, and has been fully described in its appearance and geological relations under the head of Cretaceous. This industry was inaugurated, under its present auspices, in 1877, though the same clay had been used by Mr. —— Philleo, at Red Wing, in conjunction with that taken from the bluffs of Hay creek near Red Wing, and by Mr. Boynton, for a few years prior, in the manufacture of pottery and terra-cotta work; and prior to that it had been used by the original owner, Joseph Pohl, for making pottery on the spot where it was found. At the time of the establishment of the Red Wing pottery works, Mr. David Hallem was carrying on a somewhat successful business of the same kind. He sold out to the new company and made for them their first set of moulds and their first kilns.*

The Red Wing stoneware company carry on the largest establishment of the kind in the United States, producing in 1885 the enormous amount of more than one million five hundred thousand gallons, besides a large quantity of flower pots. This establishment has never been compelled to close its work because of over-production, the quality of the ware being so superior that even in a dull season there is an increasing demand for it. It is now sold from lake Michigan to the Pacific, and from Winnipeg to Kansas City. There has been a steady growth, as the demand increased, since the work began on a small scale in 1877. Experiments lately made show the adaptability of this clay to the making of Rockingham and yellow ware, and the company are just beginning such manufacture. President John H. Rich is of the opinion that

* Of Mr. Hallem Col. Colvill writes as follows: "Hallem was a very ingenious man, and enthusiast. He had to learn kiln-making and burning by his own experiments. He was really broken down by the Akron folks who, after he had succeeded in making good ware, put the price of their ware down one-half to our dealers who were fools enough to buy, thus destroying his market and their own local enterprise."

it is simply a question of time when white ware will be produced in this state.

The Minnesota stoneware company, of Red Wing, manufacture about one million two hundred and fifty thousand gallons of stoneware annually, which is worth, on the market, about seventy-five thousand dollars. This requires the consumption of about three thousand tons of the best Illinois coal, and about one thousand cords of wood. The same clay is used here as by the Red Wing stoneware company, and is regarded equaled by none in the United States except that near Trenton, N. J. It is too fine, however, to make fire-brick a success, when used alone. The glazing clay used for the inside of vessels is from Albany, N. Y. This melts at a temperature of about three thousand degrees, giving the ware a very hard, smooth finish which resists acids. The outer glazing is formed by throwing rock-salt into the kiln when at the highest heat. The ware is burned about seventy-two hours, consuming sixteen tons of coal and one cord of wood. These facts are obtained from Mr. E. T. Mallory, the superintendent.

Peat. Not much peat is known in the county at large. Along the old valleys in the eastern part of the county are found some large peat beds. One such has been opened and experimented on, with a view to obtaining a fuel for the use of steamboats. This is situated in the valley between Wacouta and Frontenac, in which is located the Chicago, Milwaukee and St. Paul railway. Some of this peat is of good quality, but the enterprise was not carried on to success.

ARCHÆOLOGY.

The remains of prehistoric races are quite numerous in some parts of Goodhue county. They are most abundant at Red Wing, and northwest from there to near the mouth of Belle creek. They consist of the usual earth-mound, generally isolated or grouped without apparent design, and some cairns. The latter are found on the tops of some of the bluffs, but the former are more frequently on the terraces that accompany the Cannon and the Mississippi rivers in that part of the county.* Whatever date may be assigned to these

* Jonathan Carver in his *Travels* (p. 55) gives the following account of what he took for some ancient fortifications. Mr. Nicollet, on his map, (plate 7, vol. i,) places this on the low, long island, or peninsula, which lies between the Mississippi proper and the Zumbro river (Wazi Oju) after the latter enters the main valley, i. e., east or southeast from Kellogg.

"One day, having landed on the shore of the Mississippi some miles below lake Pepin, whilst my attendants were preparing my dinner, I walked out to take a view of the adjacent country. I had not proceeded far before I came to a fine, level, open plain, on which I perceived, at a little distance, a partial elevation that had the appearance of an entrenchment. On a nearer inspection I had greater reason to suppose that it had really been intended for this many centuries ago. Notwithstanding it was now covered with grass, I could plainly discern that it had once been a breastwork of about four feet in hight, extending the best part of a mile, and sufficiently capacious to cover five thousand men. Its form was somewhat circular, and its flanks reached to the river. Though much defaced by time every angle was distinguishable, and appeared as regular, and fashioned with as much military skill as if planned by Vauban himself. The ditch was not visible, but I thought on examining more curiously, that I could perceive there certainly had been one. From its situation also I am convinced that it earth-mounds, or by whomsoever made, they indicate a populous and important centre of power. According to Col. Wm. Colvill, who has gathered traditions from the old chiefs who formerly frequented Red Wing, this was once the home of the Assinniboines, a branch of the Dakotas, and the mounds were built by them, or by some of the associated bands of the Dakotas. Carver also mentions the Assinniboines as one of the "River Bands," dwelling in the region about the

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must have been designed for this purpose. It fronted the country, and the rear was covered by the river; nor was there any rising ground for a considerable way that commanded it; a few straggling oaks were alone to be seen near it. In many places small tracks were worn across it by the feet of the elks and deer, and from the depth of the bed of earth by which it was covered, I was able to draw certain conclusions of its great antiquity. I examined all the angles, and every part with great attention, and I have often blamed myself since for not encamping on the spot and drawing an exact plan of it. To show that this description is not the offspring of a heated imagination, or the chimerical tale of a mistaken traveler, I find on inquiry since my return, that Mons. St. Pierre and several traders have, at different times, taken notice of similar appearances, on which they have formed the same conjectures, but without examining them so minutely as I did. How a work of this kind could exist in a country that has hitherto (according to the general received opinion) been the seat of war to the untutored Indians alone, whose whole stock of military knowledge has only, till within two centuries, amounted to drawing the bow. and whose only breastwork even at present, is the thicket, I know not."

Of this supposed fortification Mr. Featherstonhaugh makes the following observation [Canoe Voyage, vol. i, p. 242] "L'Amirant having told me there was an extensive prairie not far from Roque's, on reaching it about noon I landed there, and ascending the bank perceived through some evergreen trees, unusual elevations about a mile and three-quarters off. Directing the boat to wait for me, I immediately walked across the prairie, a distance of about two miles, and on reaching them entertained no doubt that this was the remarkable locality seen by Carver. It certainly was a very curious place: the prairie was entirely level as far as these elevations, and the surface was completely composed of dusty sand, covering a black alluvial mould.

"The first of these certainly had the appearance of an ancient military work in ruins. It had a steep sandy slope to the bottom, and resembled a very irregular work, entirely covered with drifted sand, consisting of something like three bastions and various salient angles. Inside of the work was a large cavity, and a slope of twenty yards to the bottom. There seemed also to be the remains of terraces. Outside was what might, perhaps without exaggeration, be called a ditch, whether made by men or the wind, with a terrace of eight paces broad to the northeast. The inside of the cavity was about seventy paces in diameter, and the whole elevation was four hundred and twenty-four paces in circumference. Distant from this, about seven hundred paces south-southeast, was a second, resembling it in form and size; and seven hundred paces east-southeast from this last was a third, the largest of the three being eleven hundred paces in circumference, having, like the others, what represented bastions and salient angles, and being capable of containing one thousand people. Its walls appeared lofty, when standing on the outside, and there was a deep ditch on the south side. Further to the south I counted six more. Nor was there wanting what an observer might fairly call a communication from one to the other, and to the river, for the ground was thrown up all the way to it. From the highest point at which I stood I could distinguish a line of similar elevations extending at least four miles.

"At the northern end of this singular assemblage of elevations they most appeared to have been the work of art, whilst at the southern termination they gradually passed into an irregular surface, and became a confused intermixture of cavities and knolls, that I think might be satisfactorily accounted for by the blowing of sand. In this part, as Carver observes, were still a great number of straggling oaks.

"It is possible that all this may have been done by the wind blowing a decomposed sandstone into these forms; but from the limited opportunity which I had of examining these appearances I was far from being convinced of this. The substance of the prairie was a vegeto-alluvial deposit, having a light covering of sand upon it; and if it was the wind which had thus distributed the sand so evenly upon the surface, how are the raised lines which are continued down the river, and the elevations which so much resemble fortifications, to be accounted for? The same wind could hardly at one time lay the sand equally upon the prairie, and at another build up structures so much resembling works of art. Those, however, who think so after personal inspection, are bound to satisfy themselves why the wind has not produced similar effects upon the surface in other parts of this extensive prairie. It is difficult to suppose a force of that kind proceeding uniformly to produce effects that so extremely resemble a line of defense constructed by a barbarous people. But after all comes the question,— What were these fortifications intended to defend? Carver certainly talks somewhat extravagantly when he speaks of their being fashioned with the skill of a Vauban. I regretted not having leisure to dig about them; but the sand was so blown over the whole that it would have required a great deal of time to clear only a very small space away. Hereafter, when this curious place becomes more known and investigated, if Indian antiquities should be discovered commensurate with the extent of the work, such as the stone instruments and weapons of offense usually found about Indian encampments, it would decide the question."

Keating seems to have missed the place described by Carver. He landed at the "Grand Encampment," which was not far from the present site of Wabasha city. General Pike alludes to the place but gives no description, except to state that it was about nine miles below lake Pepin. Mr. Schoolcraft, on the authority of a trader named Hart, states these fortifications were on the right bank. On the stone cairns about Red Wing, see Minnesota historical collections, vol. 1, p 147.

These supposed fortifications have not been examined by the present survey. From all that can be gathered from a general knowledge of the valley of the river, and from the foregoing descriptions, and from the absence of further mention of them by later travelers, it is thought probable that they are due to the existence of some outliers of the sandstone which forms the lower slopes of the bluffs of the river, in the valley at that point. Such rocky foundation is probably, in part, the prime cause of the existence of the island itself. Such remnants of the once continuous formations are known at several places. The fact that these are covered by blown sand, as described by Featherstonhaugh, seems to require some source of such sand, which is afforded only by the supposition that the St. Croix sandstone is there very nearly exposed at the surface, and by winds and waters has been disintegrated.

mouth of the St. Croix. The name of this tribe has been given to the bold bluff on the north side of the Cannon on the map accompanying this report.

A great many mounds are on the lower terrace, and these are generally smaller than those on the higher terrace; yet according to Mr. C. Spates, on whose farm some of them are located, some of the lower mounds are quite as large as the upper. In the space of a square mile probably five hundred mounds could be counted, and the aggregate number, from Red Wing to Belle creek, would probably exceed one thousand. They seem to have an irregular distribution about the brink of the terraces, and along the sides of the little ravines that descend to the river.

Those on the upper flat, at Mr. Spates' house, are fromfour to six feet high, and some of them exceed six feet. One that is on the top of Barn bluff, at Red Wing, was seen by major Long in 1817 and on measurement was found to be five feet high. When the railroad was graded recently across the lower flat, on the Spates' farm, a number of these mounds were destroyed, and there were found relics, some of which have been procured for the general museum of the university. These consist of pieces of broken pottery, of the usual variety, fragments of human skulls, a bone sharpened at one end as if for use as a needle, an awl-shaped bone, evidently the penis-bone of the badger, a gray slate-colored stone pipe, incomplete, about three and a half inches long, having the bowl and draft-hole for the stem unexcavated, and a large knife or spear blade, of white, granular quartzyte, so thin that it is translucent. This last is about an inch and three-quarters in width, and when entire was probably about twelve inches in length. The piece obtained is nine inches in length. Occasionally are found arrow-points in the fields, and also on the farms further west.

TREATY MEDAL OF 1801 IN A RED WING MOUND.

At Red Wing was formerly a mound, situated on Main street, which, when removed, was found to contain a human skeleton, and with it a medal having date 1801. On one side is the date, with the head of Jefferson and his name. On the other is a representation of clasped hands, hatchet and pipe crossed, and "Peace and Friendship." It is quite a large medal, and is owned by Mrs. Frank Sterritt, St. Paul, from whom this description was obtained. In the opinion of Col. Colvill this is evidence that the Indians then living here constructed these mounds. On being questioned by Col. Colvill another old Indian said he was present and saw the burial of him that wore the medal.

The following letter from Col. Colvill conveys further information touching the probable origin of this medal, and of the mound in which it was found:

RED WING, MINN., Oct. 25, 1886.

N. H. Winchell—State Geologist, etc.:—

MY DEAR SIR: * * * * The Assinniboines, the Omahas and Iowas and the Sioux, successively dwelt along the river in this county. All were mound-builders. Of the vast number of mounds on the high terrace in Burnside township, and extending back along Spring creek and the Cannon on the same level, none have been examined for the purpose of the study of the contents, and nothing has been found about them save fragments of potter's ware and arrow-heads, turned up by the plow. The material, form and finish of these are the same as in the like articles found on the river bench below. The mounds on the margin of the high terrace are very much larger than the rest, and manifestly were constructed for some different purpose. I surmise they were exclusively burial mounds. The other mounds on this terrace, like those on the river bench, are irregular in size and form, with no order of arrngement as to situation, and like the latter, also, must have been used as dwellings. The difference in the level of the two terraces is over one hundred feet. There are a few mounds on the high bluffs differing altogether in construction and purpose from all of the others—of which, a little further on. The lower or river bench extends from Red Wing to the Cannon valley, almost three miles, and above the Cannon, along Prairie island, for six or seven miles further. This bench, in both cases, runs about a half mile wide. All this bench land is covered with mounds and there are also a great number on the same level across the river in Wisconsin. I have seen very handsome vases taken from the Wisconsin mounds, and one from the mounds on Prairie island; these were all just alike and about the same size, measuring from a pint to a quart. I have seen fragments only of larger ware. The larger ware appears to have most ornamentation and variety of form, variety of uses. You have fine specimens of the latter taken from a mound on the river bench by Mr. Spates. The material in all cases is burned and crushed, clam shell mixed with clay.

All the mounds on the river bench are said by the Sioux to have been the dwellings of the Assinniboines, and their description of them agrees with the account of the dwellings of the Manitoba Assinniboines given by the French explorers, and also with what we know of the Mandan villages on the Missouri. A pit was dug, strong upright posts set in the bottom with cross pieces atop, and the whole covered with poles, brush and earth. In case of a death within, the dwelling was filled in completely with earth, covering the remains of the dead with his arms, utensils, etc. Some of these mounds were cut through by the Cannon Valley railroad. As was to be expected, the greater number contained no human remains — a few did; all showed the burned clay bottom of the fireplace with charcoal and ashes, also blackened and scorched stones used about the fire. Our Indians say that the Cheyennes still make potter's ware after the old manner and form, and that the Sioux did until they had something better from the whites.

Our Indians say that they know nothing of the mounds on the high terrace or of those on the bluffs; that the Assinniboines lived here many hundred years ago, how long they were here — a vast length of time — a very general and vague statement.

The high terrace mounds appear to be the older; some of them have large oak trees growing upon them. These may have been built by the Assinniboines, or some earlier tribe, when the bench below was flooded or was bottom land, unfit for residence purposes. I suppose lake Pepin, but a few hundred years ago, washed the base of the high terrace; the deep and wide beds of beach gravel lying along this base show that it stood there a long time. I will mention here what I had not noticed at the time I last conversed with you on this subject. That is, that there is a strip of lake beach gravel along the river slope of the bench. This strip is only twenty feet wide and about two feet high in the middle; it shelves off from the middle on each side to an edge, the bottom lying level upon the old sand bed of the river. It is covered with three feet of clay. The islands now showing in the river do not appear to be of great age. I suppose they were laid down in the lake at the same time this gravel beach and clay bed were; these last are but little higher than the islands, and are but six feet, counting to the bottom of the gravel beach, higher than the bottom land of the river. The river bench slopes gradually, like all lake bottoms, from the foot of the terrace to this clay bank. All this shows that there was a subsidence of the lake level to the margin of the bench. A few years would then suffice for the throwing up of this new gravel beach, and then came another period of submergence, during which the three feet of clay was laid down — all requiring, at the present rate of the lake deposit, at most but a hundred years.

Our historians allow but five hundred years since the migration of the great Sioux nation to this upper country, which gives two hundred years for the construction of the two villages, the first on the terrace and the second below after the water had subsided from the bench. As there were several hundred families, and each dwelling served but for a short time, this time is ample for the construction of all the mounds and allows for three hundred years since their final abandonment.

In the year 1700, Le Sueur locates the foot of lake Pepin at a point four miles above the Beef slough outlet of the Chippewa; that is four miles lower down than now. His description shows that the Beef slough was then the main channel of the Chippewa. The slough approaches the Mississippi at but a slight angle and the bar was laid diagonally down and across the Mississippi at the same angle, making the bar alongside the slough ten miles long. Perot's Fort, which it is now conceded was situated at Wabasha, is mapped and described as being above the foot of the lake.

The present outlet of the Chippewa comes in square across the upper end of this old bar, throwing down the drift and making the dam square across the channel instead of obliquely as before. I have surmised that this change took place in the year 1728, at the time of the great flood which drowned out the French fort near the Maiden Rock and overflowed Winona prairie. We have only to suppose a great bar, of some former time, thrown down square across the channel and holding the lake to the foot of the high terrace, and the rapid subsidence of the lake when erosion commenced in this bar, accompanied as it would be by a strong current through the lake, to account for the diagonal bar, and thus the whole history is complete.

Le Sueur, also, same year (1700), locates the lower end of lake St. Croix at Pike bar, twelve miles above the foot of that lake at the present time. *Neill's History, chap.* 8. Such great changes appear since the "historical period."

I may mention in passing that our Indians locate the scene of the original quarrel between their tribe and the Assinniboines on this lower bench between Spring creek and the Cannon, where were the cornfields and village of the latter. The Sioux, a hunting party, were in camp at the mouth of the Cannon. The woman was an Assinniboine. The next year the Sioux attacked in great force and drove the Assinniboines up the Cannon to the falls, after a number of battles. From thence the Assinniboines escaped to the head of Prairie island and up the St. Croix, and across near the Sioux villages to the Crow Wiug; thence up that stream to the Red river valley, from which, after a few years, they were expelled by the Y-hanktons.

Our Indians ascribe the legend of Winona to the Assinniboines and many of their own local names, as H-remnecha for Lake Pepin, Minnesota for the Mississippi, etc. They say that the real "azure of the skies" is intended by the word "Minnesota," not "blear water," and that the contrast, in their minds, is with the amber-swamp-water of the north.

The Omahas and Iowas came here after the expulsion of the Assinniboines, with whom they had been a loug time at war. They had villages at North Pepin, Lake City and at the mouth of Belle creek on the Cannon. This latter village was known to the Sioux as the village of the great Tepee, from the name of the stream given because of the large dome-shaped white rock near its course. Is not that the village referred to by Le Sueur under a similar name?

I have not examined the mounds at North Pepin. Those at Lake City are very interesting. About a half mile back from the lake, and near the county line, is a cluster of twelve mounds. Eight are in a circle with intervals of two rods, two on the east and two on the west outlying with same intervals. These mounds are all of a small size, not more than ten feet across and two feet high, but are perfectly round and exactly of the same size. Our Indians say they are Omaha mounds. The purpose of their construction and their contents are unknown.

The mounds ou the bluffs are generally loose piles of stones, having a circular opening extending vertically from the apex to the base of the pile. It is large enough to allow a man to stand erect within. They remind one of watch towers or signal stations; with proper draft, easily provided for, they would send up from a small fire a "pillar of smoke." .They are quite recent, as a cedar stake or post was taken from one of them in the year 1852. As the Sioux have no knowledge of them I suppose them to be Omaha mounds.

The mounds on the terrace at Belle creek are like those of the Assinniboines — those on the delta. A large number are very low and indistinct, and appear to have crumbled from bark or pole tepees. They had the weeds about them peculiar to Indian villages as noted by Nicollet. The Indians know this to have been an Omaha village. One large mound on an isolated knob near the creek is turtle shaped with prominences for the head and feet.

The Omahas and Iowas were driven out of this state and beyond the Missouri, mainly in one campaign led by Red Wing and Wapahasha. The Menominees were privy to the plans of the Sioux, but took no part in the war; perhaps furnished canoes and horses. The Sioux marched by the head-waters of the St. Croix and Chippewa, down the Wisconsin, beginning the attack at McGregors. The Y-hanktons reiuforced them on the upper course of the Minnesota.

The Sioux undertook this war for the purpose or settlement in the country which they had always claimed to own since the expulsion of the Assinniboines. It was after Wapahasha had received his red cap and commission as head chief from the British. Wapahasha especially achieved great glory in the conduct of the war. This title as head chief not being allowed by Red Wing, Wapahasha removed with the greater part of the band to Winona. Red Wing's titular name was Wacouta — "the shooter." This was always the head chief's title — the same as that of the chief who captured Hennepin. He had the name of Red Wing, Koo-poo-hoo-sha, from the swan's wing, dyed scarlet, which he carried. Wapahasha had his name from his red "coupe stick," which was wound with scarlet ribbons and surmounted by a white horse-tail, dyed a brilliant red. This he used to signal and direct his warriors in battle, sometimes as a standard to rally them.

Red Wing and his contemporaries here, retained their old custom of mound burial, such as is described by Carver in his account of the cave at St. Paul. His spring and summer camp was along the west bank of Jordan stream in this place. The Indians called the stream Cold Water creek. The upper end of the camp was a little above Main street. There was an oak grove a short distance behind the camp on slightly higher ground, and commanding a broad view of the river scenery. In this grove were a number of mounds when I came here — 1854 — mostly of small size, one conspicuous, over twenty feet across and three feet high. It was at the southwest corner of Main and Broadway crossing. In grading the street this was leveled and along with very badly decayed bones was found a Jefferson medal of the year 1801. After Red Wing's time the Indians coffined and buried the dead, same as the whites. Big Buffalo, his successor, was so coffined and buried, about 1820. Now, Lieut. Pike, on his return from the source of the Mississippi in 1806, stopped two days with Red Wing at this camp, and was very hospitably entertained. On his way down he had been reminded by Little Crow, at the mouth of the St. Croix, of his promised medals, promised at the treaty of the fall before at Pike islaud. One ot the head men of Red Wing's baud signed that treaty; Red Wing, from old age, was not present. Red Wing was friendly to the Americans; Wapahasha had his commission from the British. This was talked over. Altogether, if anyone was entitled, Red Wing was, to one of the medals. Of course, Pike's promises were sacredly kept. It is no objection that the date is 1801, as it was the custom to strike the medal the first year of the new administration and the die was preserved until another president took his seat. Big Buffalo's was a Madison medal of the year 1809, but which he could not have received until 1816, for he fought with the British in the war of 1812–15, and surrendered his old medal, if he had one, to them on receiving their flag. Big Buffalo was originally buried at the corner of Main and Plum streets, and when the town was laid out was removed to College bluff, and about 1870 his medal was stolen from the grave and fell into the hands of a stranger, to whom it is worthless, and is lost to us.

The Jefferson medal is now held by Mrs. Frank Sterritt, of Merriam Park, in trust for our Red Wing library association. I think the above facts make a good case for it, as having in very deed been worn by Red Wing.

I may say a lady of St. Paul, interested in this medal, looked up all the Indian treaties of Jefferson's administration relating to Minnesota or Minnesota Indians. She did not find the name anywhere, except in a treaty made with the Choctaws, who in it agreed to "keep the road to the Minnesota river open." As at that time the present Minnesota river was unknown either to Indian or white man by that name, of course the reference is to the Mississippi under its old name and is very interesting as showing the common origin of Sioux and Choctaw. The latter, it is well known, migrated from the Carolina or Virginia coast to the Mississippi and was one of the tribes first encountered by the English in their settlement at Roanoke and on the James. Did the Choctaws build mounds? * * * * * * *

W. Colvill.

Near White Rock is a conical mound that probably consists of the St. Peter sandstone. About four and a half miles from White Rock is the Potato mound, which probably consists, according to Dr. J. H. Sandberg, of drift. The top may have been used for burial.

CHAPTER III.

THE GEOLOGY OF DAKOTA COUNTY.

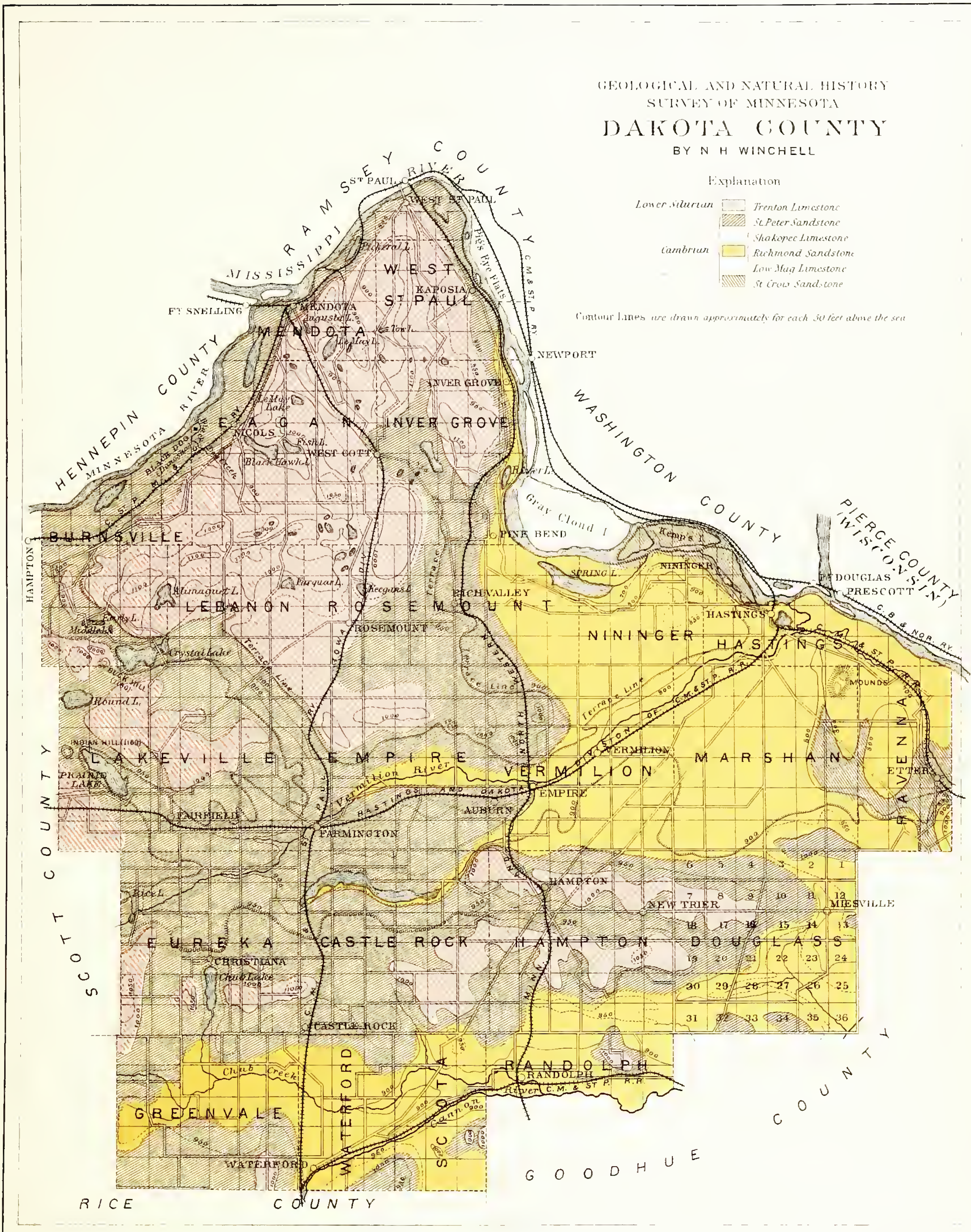
BY N. H. WINCHELL.

Situation and area. Dakota county lies north of Goodhue and Rice, and completes the apex of the angle between the northeastward-flowing Minnesota and the southeastward-flowing Mississippi. West St. Paul is in this northern apex, and Hastings, the county seat, is near the southeastern angle. Farmington, Mendota, New Trier and Nininger are its other principal towns. The county has an irregular shape and several fractional townships, due to the fact that its boundary is often formed by rivers. The total area of the county is 611.32 square miles, or 391,242.57 acres, of which 387,753.96 acres are land and 3,488.61 acres are water.

SURFACE FEATURES.

Natural drainage. Along the whole northern boundary of the county, with a sharp angle running north to St. Paul, is a great drainage course, consisting of the Minnesota and Mississippi valleys. The entire surface drainage, however, enters the Mississippi; but one creek worthy of a name or representation, entering the Minnesota. Hence the main water-divide is in the western part. The Vermilion river crosses the county in a northeastern course, joining the Mississippi at Hastings. Its tributaries descend from about one thousand feet above tide-level, where they cross the western border of the county, to six hundred and sixty-eight feet, low water in the Mississippi at Hastings. The Cannon river, with its northern fork, generally known as Chub creek, drains the southern tier of towns. Its other tributaries are Pine creek and Trout brook.

The Minnesota river is sluggish in its flow along its northwestern boundary, maintaining a level not far from 700 feet above the sea. At Fort Snelling, where it unites with the Mississippi, its level at low water is 688



Julius Bien & Co lith

feet; but it rises in time of flood to 710 feet. The Mississippi thence descends to 685 feet, low water at St. Paul, 676 at Newport, 669 at Nininger, 668 at Hastings, 667 at Prescott, and 663 at Red Wing. The Cannon river, where it enters the county in Waterford township, is 890 feet above tide, at Randolph it is 850, and at Cannon Falls about 800.

In the western part of the county, and more particularly in the northwestern, are numerous lakes. These are reservoirs that extend the high stage of the streams that drain them far into the warm season. This water is clear, pure and sometimes nearly soft. The lakes lie in a region of morainic till, and generally have pebbly shores and are comparatively deep.

Water-power mills in Dakota county.

On the Vermilion river: the Empire mill is owned by John Becker, on the S. E. ¼ of sec. 30, Vermilion. It is furnished with three run of stone (one is for feed), and one twenty-inch Leffel wheel, giving eighteen horse-power, from a fall of fourteen feet of water. The capacity is about fifteen barrels per day.

At Bridgeport is the *Gardner mill*, with a capacity of five hundred barrels per day. It has fifty-one feet head of water, but is aided by steam when the water is low. It has the American turbine wheel, thirty-two inches in diameter, giving one hundred and sixty-six horse-power, and is equipped with the Ray roller.

The *Ramsey mill*, owned by Fred Voigt, is a short distance below this. It has the Swain forty-two-inch roller, nineteen feet head of water, forty horse-power, and an average capacity of one hundred and forty barrels per day.

The *Joe Ennis mill* is about a mile above Bridgeport. It has ten feet head of water, fifteen to twenty horse-power, derived from two wheels, of which one is Leffel's and the other is unknown, one double set of rollers, four pairs of stone (two being for feed), and a capacity of about forty-five barrels per day.

On the Cannon river: the Cannon river manufacturing company own the *Grange mill*, situated on sec. 30, Waterford, having seven and a half feet fall of water, one thirty-five-inch Leffel wheel, giving fifteen horse-power, and five Huston wheels, one thirty-five inch, two forty-inch and two forty-five-inch, ten single rollers, and four buhrs, the daily capacity being about one hundred and eighty barrels.

Topography. Dakota county exhibits a great variety of surface. It presents the same contrasts in this respect as Rice county, but the extremes are greater. The western and northwestern portions are rolling, or even hilly; the southern and southeastern are flat, or simply undulating; in the extreme southeastern this flatness gives place to a bluffy and rather rough general contour, due to the excavation by streams into the surface of the country. In the northern part the surface is rough because of accumulations of material in heaps and ridges; in the central part this material is spread out evenly, not only losing its own natural roughness but filling up effectually all pre-existing gorges and other inequalities in the rocky substructure; while still further south, where this drift sheet is thinner, and the erosion by surface drainage was concentrated along certain valleys, the country is made rough by the gorges that have been excavated in the rocks. The hills in the west and north are covered by timber; the plains in the central part are natural prairies, and the bluffs and sandy soils in the southeast are sparsely covered by small oaks and hazel brush. The northern hills have a gravelly soil, or one of stony clay with gravelly and stony subsoil, the plains are fertile with a loamy soil and subsoil, and the bluffs and gorges in the southeast are frequently stony, or have a rather sandy surface with a gravelly subsoil. The hills are interspersed with lakes of clean and pure water, and have numerous springs and crooked brooks. These gather into more moderate and gently-flowing streams, as they cross the lakeless plains eastward, and, when they enter on the precipitous descents among the bluffs near the Mississippi, they are augmented by subterranean brooks that issue in the gorges, and then hurry on with violence and sometimes destructive momentum to the Mississippi. The hills in the northwest are about three hundred feet higher than the plains in the central part, and the latter are about three hundred feet higher than the drainage valley of the Mississippi in which all the waters find their quiet level.

Those great rivers, the Minnesota and Mississippi, which form the northern boundary, exhibit between themselves the same striking contrasts. Their valleys unite at Mendota, but there is a total change in the characters of the bluffs, and of the adjacent country, in passing over an interval of a few miles. The Minnesota has drift-bluffs, the Mississippi's are cut into the rocky substructure about two hundred feet, increasing toward the southeast to more than three hundred. The Minnesota is a slow and often muddy stream, but subject to sudden and destructive floods; the Mississippi's water is clear, and of a more steady stage. The Minnesota has wide prairie bottom-lands, with timbered hills at a distance; the Mississippi has timbered bottom-lands, with high prairies in the distance.

The Vermilion and the Cannon rivers flow eastward through the county, exhibiting gradual transitions from the characters of the Minnesota valley to those of the Mississippi. Their tributaries rise among the gravelly hills in the western part, as rippling brooks with timbered banks. As they emerge from the timber, where their courses have been crooked, and enter on the plains, their channels are straightened, and the sun in summer has direct action on their temperature, or the cold of winter shuts them with an effectual covering of ice. As they acquire greater volume in the eastern part of the county, and are again protected by the high rocky banks, and moderated in temperature by the incoming of copious subterranean tributaries, they maintain such an equlibrium that they become a resort for the speckled trout—these being the most northern tributaries of the Mississippi from the west, so far as known, in which that fish is found. It is seldom that in so short an interval so great topographic variations can be seen. This series of changes generally requires a space of a hundred miles, or more, to complete the shift from one extreme to the other. It is here accomplished in twenty miles. This change is here caused by a single agent—the ice period—acting on a uniform rock surface. It prevailed, it faded out, it ceased. These steps are legibly marked both in time and in geographic area. It prevailed first in the north and northwest. It faded out first in the central part. It ceased first, or never acted, as an ice-period, in the southeast. The whole expanse from the Minnesota to the Mississippi is underspread by the same series of alternating limestones and sandstones.

Elevations. So far as known, the highest points in the county are somewhat over eleven hundred feet above the sea. These are in Burnsville, Eagan, West St. Paul and Inver Grove. These elevations were ascertained, primarily, by the use of an aneroid barometer, referred to adjacent railroad levels, but into this determination enters some doubt, especially when the contours for adjacent hills and ridges are extended from known points by estimates by the eye. It is quite possible that some hills attain the hight of twelve hundred feet. The contour lines which are seen on the county map convey a correct idea of the general topography, but fail entirely to express the multiplicity of change, and the individual hills and valleys in the rolling districts in the morainic areas in the northwestern towns of the county.

The following lists give reliable data from which future measurements may be made:

Elevations on the Chicago, Milwaukee and St. Paul railway, River division.

	Miles from St. Paul.	Feet above the sea.
St. Paul, low water in the Mississippi river,	0	685
St Paul, grade of the St. Paul and Duluth railroad,	0	706
St. Paul, grade at Dayton's bluff,	1	709
Newport,	8	751
Langdon,	13	816
Hastings, junction with the Hastings and Dakota division,	20	709
Etter,	28	691

Hastings and Dakota division of the Chicago, Milwaukee and St. Paul railway.

	Miles from Hastings.	Feet above the sea.
Hastings, junction,	0	709
Edge of prairie, sec. 5, Marshan,	3	826
Summit, sec. 21, Vermilion (cutting 8 feet),	9.5	826
Auburn,	12	861
Sec. 27. Empire,	15	888
Farmington, crossing Iowa and Minnesota division,	18	903
Fairfield,	23	942
Summit, near the west line of Dakota county (cutting 10 feet),	26.5	1080

Iowa and Minnesota division of the Chicago, Milwaukee and St. Paul railway.

	Miles from St. Paul.	Feet above the sea.
St. Paul, Union depot,	0	706
Mendota Junction,	5.5	721
Crossing of the Chicago, St. Paul, Minneapolis and Omaha railway, Mendota,	6	737
St. Paul Junction,	6.5	759
Summit (cutting 5 feet),	11	899
Westcott,	12.6	882
At a lake two miles south of Westcott,	14.6	914
Summit,	16	973
At Kegan's lake,	16.5	948
Rosemount,	18	959
Vermilion river (bottom 888),	25.7	897
Farmington, crossing of the Hastings and Dakota division,	25.5	900
Farmington depot,	26	903
Divide, one mile south of Farmington (natural surface 913),	26.6	902
Divide, on sec. 18, Castle Rock (natural surface 1013),	29	1002
Castle Rock depot,	31.6	934
Foot of slope, 5 miles from Northfield (natural surface 919),	33.1	912
Chub creek (water 917), grade,	33.7	923
Foot of slope near Chub creek,	34.6	927
North end of plateau, three miles north of Northfield (natural surface 968),	35.1	958
South end of plateau, two miles north of Northfield (natural surface 981),	36.1	969
County line,	37	970
Northfield depot,	38.1	915

From Cannon Falls to Northfield.

	Miles from Red Wing.	Feet above the sea.
Cannon Falls depot,	21.3	816.5
County line,	22	826
Paxton's glen (bottom, 826),	22.5	841
Crossing of the Minnesota and Northwestern railway,	27	876
Chub creek (bottom, 859),	30.1	877
Creek (bottom, 879),	34.5	899
Waterford,	34.6	902
Crossing of the Wisconsin, Minnesota and Pacific railway,	35.3	912
Northfield depot,	36.5	915

On the Chicago, St. Paul, Minneapolis and Omaha railway.

	Miles from St. Paul.	Feet above the sea.
St. Paul,	0	704.4
Mendota,	5.5	724
Nicols,	9.9	712
Hamilton,	17.7	720

On the Minnesota and Northwestern railway.

From profiles in the office of H. Fernstrom, St. Paul.

	Miles from St. Paul.	Feet above the sea.
Union depot, St. Paul,	0	704
Bridge over the Mississippi river,	0.1	712
West St. Paul,	0.8	704
Inver Grove,	7.6	721
Summit, grade,	13.3	905
Rich Valley,	15.9	863
Summit, grade,	17.7	928
Vermilion river (bottom 836),	22.4	852
Empire,	22.5	856
Summit, grade,	23.4	886
Little Vermilion (bottom, 852),	24	880
Hampton (a summit),	26.6	984
Depression, grade,	27.5	961
Summit, grade,	28.2	984
Randolph,	32.7	878
Chub creek (bottom, 862),	32.9	876
Cannon river (bottom, 846),	33.3	874

Elevations on the Wisconsin, Minnesota and Pacific railway.

From profiles in the office of engineer Hoffman, St. Paul.

	Miles from Waterville.	Feet above the sea.
Northfield,	29.9	910
Line of Rice and Dakota counties,	31	897
Waterford,	32	903
Granville,	37.7	893
Chub creek (low water, 862; high water, 867), grade,	38.5	874
Line of Dakota and Goodhue counties,	43.6	841
Cannon Falls depot,	45.1	814

Average elevation of Dakota county. Following are estimates of the average elevation of the various towns of this county: Hastings, 775 feet above the sea; Ravenna, 800; Nininger, 800; Marshan, 900; Douglass, 960; West St. Paul, 1000; Inver Grove, 980; Rosemount, 950; Vermilion, 900; Hampton, 980; Empire, 930; Castle Rock, 950; Waterford, 930; Sciota, 900; Randolph, 870; Eagan, 990; Mendota, 900; Burnsville, 910; Lebanon, 960; Lakeville, 975; Eureka, 960; Greenvale, 940. Allowing for the different sizes of these townships, the average elevation of the county becomes about 960 feet above the sea.

Soil and timber. As the natural topography depends so closely on geological causes, and introduces in this county a great diversity, so the soil and timber show great variations in short intervals. Nearly all the grand distinctions of soil that can be found in the state are exemplified here in one county, these all depending on the same grand causes as operated at large to bring about the same varieties throughout the state, viz.: (1) Red till soil; (2) gray till soil, timbered; (3) gray till soil, prairie; (4) loam with gravelly subsoil; (5) laminated clay soil and subsoil; (6) sandy soil, with sand or fine gravel as subsoil; (7) alluvium. In general, it should also be stated that these distinctions are all somewhat obscured by a later loam-cover which has a varying thickness, and which tends to give a semblance of homogeneity to the soils of the county, as it does also to those of nearly all the state. In general these soils are distributed in the county as follows:

(1). *Red till soil.* This occupies the uplands of West St. Paul, Inver Grove, Mendota, Eagan, Lebanon, central Burnsville. It fades out into a loam with a gravelly subsoil (4), in northern Rosemount and southern Lebanon.

(2). *Gray till soil, timbered.* This occupies southern Burnsville, western Lakeville, western Eureka* and western and southern Greenvale. It fades out eastwardly into a gray till soil of prairie (3), and changes rather abruptly to a red till soil (1), in southern Burnsville.

(3). *Gray till soil, prairie.* There is a tract of high till prairie throughout the most of the eastern half of Lakeville, the eastern part of Eureka and over a large part of Greenvale. There are also considerable tracts of this, with more or less of a loam-cover, that forms the immediate soil, in western Rosemount, northern Empire, much of Castle Rock, Waterford, Sciota, Hampton and Vermilion. There is also, in the northeastern corner of Marshan, sec. 1, an isolated area of the same, known as "the mounds," which rises a hundred feet, or more, boldly above the surrounding plain, making a well-known landmark. All of these easterly prairie tracts of gray till soil are somewhat doubtful in their characters, and unknown in their actual extent, because of the prevalence of a later-formed surface loam, the origin of which it is not necessary here to discuss.

(4). *Loam with gravelly subsoil.* Distinctively this coincides with and constitutes the great central prairies of the county, but it gradually fades, upward, into the last foregoing, and downward into numbers six and seven. That is to say, it occupies southern Lebanon, northeastern Lakeville, the valley known as Rich valley, extending from near Mendota through Eagan, southeastwardly, through Inver Grove, over eastern Rosemount and thence down the Vermilion valley. It also includes a higher plain, that on which

* About Chub lake and in the southwestern part of Eureka the subsoil is red till.

Rosemount station is situated, taking in much of southern Rosemount, northern Empire and Vermilion, the most of Marshan, southern Nininger, and the upper flat in southeastern Vermilion. This kind of soil is found also in numerous other, more restricted, areas, and of these more especially should be mentioned the great terraces that accompany the main rivers of the county. Such are particularly noticeable along the Cannon in Sciota and Randolph, and in patches all along the Mississippi from St. Paul to the Goodhue county line. The Vermilion river, in like manner, has marked terrace plains spreading out on each side all the way from Eureka to Hastings, composed of water-strewn gravel which forms the basis of this kind of soil.

(5). *Laminated clay soil and subsoil.* This kind of soil was noted, in the survey of the county, in only two places, but it probably exists much more generally, as it is one that easily becomes covered by other loose drift materials and has therefore escaped observation. The lower hills, and northward slopes of the uplands in Mendota and in northern West St. Paul are covered with this soil. It was also seen in Nininger, covering much of secs. 24 and 19, where it is found on the highest land in that vicinity

(6). *Sandy soil with sand or fine gravel as subsoil.* This is found distinctively in the lower portions of Marshan, Ravenna and slightly in northeastern Douglass, where it is known by the sandy "oak-openings" which there prevail. Minor patches of the same kind of soil are found in other parts of the county, but they are generally due to other causes than are those that have been mentioned. They are in the close vicinity of outcrops of some crumbling sandstone, and to that this looseness can be referred. The St. Peter sandstone is the most frequent cause of such isolated patches of sandy soil.

(7). *Alluvium.* The bottom-land soils along all the present streams are here included. Not only so, but the ancient alluvial plains, particularly the lower flats of such old valleys, are still so richly covered with humus that they could be included in some cases in this designation. The old valleys that extend from Crystal lake, and from Lakeville lake southeastwardly, finally reaching the valley of the Vermilion, as well as the well-known Rich valley, could be here included; but as their subsoils are generally and quite evidently constituted of gravel these old valleys have above been grouped under (4)—*loam with gravelly subsoil.*

The rolling till soils are covered with a heavy and varied forest. On the red-till soil oak is very abundant, and it is probably the predominating genus over more than three-fourths of the county, as it spreads, with its different species, over the scantily timbered towns in the central and eastern parts. On the gray till areas the forest growth is much more luxuriant, both in size and in the number of species. The gray till is more clayey than the red, and more calcareous. Here are found all the species that have been mentioned as characterizing the "Big Woods" of the state. They have been enumerated in the report on Rice county.*

The geological structure.

The bedded rocks of Dakota county are included in the following tabulated series:

Lower Silurian	Trenton shales,	about 125 feet.
	Trenton limestone [perhaps includes the Chazy],	20 feet.
Cambrian	St. Peter sandstone,	130 feet.
	Shakopee limestone,	25 feet.
	Richmond sandstone,	80 feet.
	Lower Magnesian limestone,	about 140 feet.
	Jordan sandstone,	about 100 feet. St. Croix.
	St Lawrence limestone, with shales,	seen about 75 ft.

On the surface generally these rocks are covered with the drift materials, but by the examination of the few scattered outcrops, and by comparison with the ascertained geology of surrounding counties, the rock that underlies the drift in nearly all parts of the county is pretty certainly known. Besides the rocks noted in the foregoing scheme, there is some reason for believing that the Cretaceous is represented, in a feeble way, within Dakota county. These formations will be considered in the same order as in the chapter on Goodhue county. Their geographic areas are shown on the plate of the county (plate 34).

St. Lawrence limestone and shales. This is the lowest part of the St. Croix that is known in the county. It is but poorly exposed, and is confined to the bluffs of the Mississippi river below Hastings, and even there it is so hid

* Final report, vol. i, p. 652. Compare "The flora of Minnesota," twelfth annual report. The sugar maple is found on islands in Crystal lake, but generally not on the main land in that vicinity. White pine is at the "big falls," three miles west of Cannon Falls, and at Pine Bend on the Mississippi. Balm of Gilead grows at Crystal lake. Chestnut is in cultivation, S. E. ¼, sec. 28, Waterford. Black Walnut is native at Spring lake, near Nininger.

by the talus of fallen fragments from above, and by the drift, that no facts worthy of mention, concerning its lithology within Dakota county, can be added to the descriptions that have been given of it in the last two chapters. It is the northward extension of No. 2 of the section of the St. Croix sandstone, given in the report on Goodhue county.

The Jordan sandstone. The only exposures of this rock within the county are near Hastings, but here some irregularity in the stratigraphy of the Cambrian interferes with any attempt that may be made to define exactly the stratigraphic position of the outcrops. This irregularity extends northeastward,* and crosses the St. Croix valley a few miles south of Stillwater.

In the bluffs alongside of which the river division of the Chicago, Milwaukee and St. Paul railway runs, on the east side of the Mississippi river, north of Hastings, the precipitous rock-bluffs consist almost wholly of the Lower Magnesian limestone, rising about one hundred feet perpendicularly. Underneath this limestone, near the railroad bridge over the Mississippi, can be seen a few feet of white sandstone, which can be no other than that here considered. This is nearly on a level with the railroad grade, not rising more than thirty-five feet above the river at low water. Immediately across the river, at Hastings, this limestone is found in the streets of the city and passing down to and below the level of the water in the Mississippi, without the appearance of any sandstone. In the deep well drilled at the depot, at Hastings, this sandstone was struck after passing through eighty feet of dolomitic limerock. The stratification being about horizontal on each side of the river, it seems necessary to infer a fault in the formation, the change of place of the rock on the south and east having been a down-throw of about one hundred feet. The line of this fault can be rudely located running southwestwardly, crossing the Mississippi river about in the western limits of Hastings. Point Douglas and Hastings are on the southeast side of the break. On the northwest side of this irregularity the beds of this sandstone can be seen in the bluffs of the Mississippi. Of this irregularity Dr. D. D. Owen states: "Still ascending the stream, the strata take a local rise, so that three or four miles above the mouth of the St. Croix the sandstone again emerges from beneath the water and rises to the hight of twelve or fifteen feet above low-water mark." In a colored section illustrating this change (sec. No. 5, of Owen's

* See the report on Washington county. Also compare the annual report of the Wisconsin geological survey for 1877, page 37, and Geology of Wisconsin, vol. iv, p. 107.

report on the geology of Iowa, Wisconsin and Minnesota), the line of this fault is vividly depicted, crossing the whole thickness of the exposed rock, cutting the Lower Magnesian from top to bottom, the down-throw being on the south-east side. At Nininger this sandstone rises from the water-level about eighteen feet, and can be seen at the old boat-landing.

The Lower Magnesian limestone. The thickness of this limestone is about one hundred and seventy feet. This is obtained by uniting the thickness penetrated in the deep well at Hastings (eighty feet) with the thickness exposed in the bluffs, above the mouth of the well, along the right bank of the Vermilion river at Hastings.* It is exposed in the right bank of the Mississippi, both below and above Hastings. In the western limits of Hastings begins a line of fault, or other irregularity, as has been stated in describing the underlying sandstone, which runs southwestwardly and crosses the Cannon river probably in Waterford or Sciota, running toward Northfield. This limestone underlies the lower gravelly plain that extends from Nininger to Hastings, and which expands from Hastings on either side of the Vermilion, westwardly and southwardly, having an elevation of about eight hundred feet above the sea. Although this plain is composed superficially of gravel and a later loam, yet its continuity and perhaps its hight, are mainly dependent on this limestone. It is separated, by a distinct terrace-shoulder, from a higher plain which has an elevation, in the eastern part of the county, of about nine hundred feet above the sea. These both have a perceptible slope toward the Mississippi, and superficially are composed of the same materials, but along the bluffs of the rivers the nucleus of the upper is found to be likewise a limestone, the Shakopee. The slope eastward is due to the pose of the transported gravel with which the rocks are covered, as explained under the head of the drift.

At Bridgeport, near Hastings, the falls of the Vermilion are produced by the first plunge of the water from the top of the Lower Magnesian, the fall being about twenty-eight feet, though the whole descent is about fifty-one feet. There is a dam above the fall, and a short rapid below.

The quarries in the bluff of Spring lake (which is in the bottom land of the Mississippi), a short distance above Nininger, are in this limestone. It here extends from the water-level of Spring lake to one hundred and twelve feet above it, judging from the hight of the lower terrace. They are situated on the section line between secs. 20 and 21, Rosemount. The visible beds are horizontal, heavy, vesicular, and rise only about fifteen feet above Spring lake. The high bluff, however, just west of Nininger rises one hundred and ninety feet above the lake and contains at least one hundred and seventy-five feet of limestone. This bluff is perpendicular on its western end (sec. 13, Nininger) and along the north face.

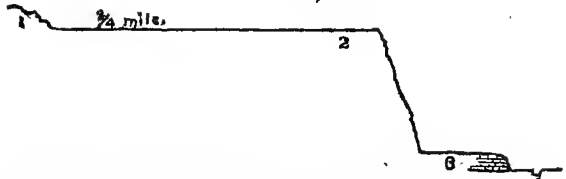
* It is not improbable that this thickness includes also the Shakopee, by the omission of the Richmond sandstone, as described in the report on Goodhue county.

At Nininger the strike of the Lower Magnesian is distinguishable from that of the Shakopee. The flat on which the residence of Hon. I. Donnelly stands is supposed to be underlain by the Lower Magnesian limestone; that of Mr. G. O. Robertson is on the edge of the bench formed by the Shakopee, one being about sixty feet higher than the other. Apparently these two limestones combine by the omission, mainly, of the Richmond sandstone, and constitute the one massive bluff west of Nininger in the same manner as in the Assinniboine bluff in Goodhue county; and this may be true at Hastings where the thickness of limerock on the southeast side of the fault has been given at about one hundred and seventy feet. Indeed this uncertainty about the Richmond sandstone, and the introduction of this fault in the formations of the Cambrian, united with the morainic abundance of the drift-materials in that part of the county where these strata would otherwise be exposed, must be offered as the only reasons for some indefiniteness in these descriptions.

The Richmond sandstone. The only evidence of the existence of this sandstone in this county is derived from other sources than actual observation. Two parallel terraces have been mentioned in describing the Lower Magnesian limestone, the upper one of which is supposed to be due to the persistent strike of the Shakopee limestone, and the lower to that of the main body of limestone. In order that this shall be so there must be an intervening more erosible rock, the more rapid disintegration of which caused the down-throw and recession of the upper limestone. These terraces consist outwardly of drift, being in the trail of one of the most powerful morainic accumulations of the state, and their underlying firmer rock-bases are seen only at a few points. The supposed sandstone stratum which here is appealed to as a cause for the separate strike of these limestones is everywhere invisible.*

The Shakopee limestone. This rock is seen in the right bank of the Mississippi, first, along the east side of sec. 27, West St. Paul, near the point where the line between secs. 26 and 27 intersects the shore. The following diagram shows the composition of the bluff near the line between secs. 2 and 11, Inver Grove:

Fig. 3.



West bank of the Mississippi at Inver Grove.

Explanation.

1. Rolling and timbered Trenton border, covered by red till, rising from twenty-five to fifty feet above the alluvial terrace.
2. Alluvial terrace, rising one hundred and twenty-two feet above the river at medium stage, and about seven hundred and eighty-five feet above the sea.
3. Shakopee terrace, twenty-seven feet above the river.
4. Channel of the Mississippi.

* See the report on Goodhue county, where such terraces are described at Cannon Falls. Also compare the fourteenth annual report, p. 329.

The Shakopee terrace here is in all respects like the same terrace seen along the Minnesota valley above Shakopee, and is covered with large boulders. The rock also appears like the same formation at Shakopee. The preceding diagram and measurements were made on the land of Mr. P. Barton.

The level of this limestone rises higher and higher above the river, in going south, until it reaches the hight of the alluvial terrace of the above diagram, and even exceeds it. It is one hundred and twelve feet above the level of Spring lake on sec. 20, Rosemount, this lake being about eight feet above the river. About a quarter of a mile south is another flat rising about eighty feet higher, this being coterminous with the foregoing alluvial terrace toward the north, though here increased in hight above the Mississippi by detritus from the northwest coming down the Rich valley.

In the north half of sec. 27, Nininger, the descent from the high flat prairie, toward the river, northward, is divided near the top into two parts by an intermediate terrace. There is no rock visible here, bnt the topography indicates the presence of the Shakopee and the Richmond sandstone under erosive agents.

The top of the Shakopee, N. W. ¼ of sec. 24, Nininger, which is involved with the Lower Magnesian in the bluff east of Spring lake, is one hundred and ninety feet above Spring lake.

At Nininger the strike of the Shakopee is visible through the village, deeply buried under loam and gravel constituting the higher flat, on which the house of Mr. G. O Robertson stands. The highest ground here, however, rises about fifty feet higher than the Shakopee, in the neighborhood of the Grange Hall, being about two hundred and twenty feet above the river at the boat-landing, or somewhat more than nine hundred feet above the sea. From this level the ground slopes, generally with uniformity, through the village northward, down to the level of the top of the Lower Magnesian limestone.

Southeast from Hastings, beginning on the south side of the Vermilion river, near Bridgeport, are elevations that suggest the existence of patches of the Shakopee limestone. This rock is not exposed in any of these elevations, and so far as can be seen they consist of till.

Toward the west, in the interior of the county, are some interesting localities which give some indication of the course of the fault which has been mentioned. The line of the terrace which extends along the north side of the Vermilion river from Hastings westward to Empire station, on the Minnesota and Northwestern railway, coincides nearly with the direction and location of this break, and suggests the relation of cause and effect, though no exposure of rock is known along the Vermilion valley* till reaching the small quarry of Thomas Redican on sec. 21, Vermilion, and the mill on the S. E. ¼ of sec. 30, Vermilion, on the south branch of that stream. Here, on the right bank, near the mill, is a bluff of rough magnesian limestone layers, which rises so high above all other exposures further east and northeast that they must be assumed to be on the westward side of the fault. This is about one hundred feet higher

* In the road between secs. 10 and 11, Vermilion, where it descends from the upper flat to the lower, at the S. E. ¼ sec. 10, are fragments of magnesian limestone on the brow of a little terrace which runs E. and W. along the river, about eighteen feet above the river.

than the top of the limestone at the mouth of the Vermilion, which is on the eastward side. If there were no fault, the natural dip would require this exposure to be lower than the rock at the mouth of the Vermilion. This rock probably belongs to the Shakopee horizon. About thirty feet of rather thin loose layers are here exposed, somewhat wrought for use in the basement of the mill; owned by John Becker.

The Shakopee is exposed along the road between sec. 35, Castle Rock, and sec. 2, Sciota, rising about twenty feet above the flat prairie. To the south of it several mounds of the St. Peter sandstone rise up in the prairie fifty or sixty feet.

The creek which crosses sec. 34, Castle Rock, cuts eighteen feet into the Shakopee where it crosses the town line. These points, which are about nine hundred feet above the sea, are supposed to be on the west side of the fault, while at Cannon Falls, where the Shakopee is well identified as a stratum, distinct from the Lower Magnesian, the top of the Shakopee, though about nine miles further east, is only eight hundred and thirty-four feet above the sea, and must be considered on the east side of the fault.

In the Cannon valley, in the western part of Randolph, are curious, small, isolated mounds that have the appearance of being made up of St. Peter sandstone rising from fifty to seventy-five feet; but they do not reach the hight of the surface of the Shakopee limestone already described along the north boundary line of Sciota, and hence seem to be situated on the east side of the fault already mentioned. The fault must therefore pass through Sciota township, entering it in sec. 1, and perhaps remains on the north side of the Cannon river to the vicinity of Waterford station. On approaching the village of Cannon Falls the railroads that run to Red Wing separate about a quarter of a mile, the Milwaukee road, the southern of the two, descending along the highest (Shakopee) terrace, the edge of which it skirts in such a way as to cut into the Shakopee about fifteen feet, revealing a very confused and undulating stratification, some of the layers being three or four inches, and some of the lower ones about eighteen inches, the former rising and falling somewhat, as the thicker strata swell out concretionally.

The outcropping edges of the Shakopee limestone appear at Hamilton, on the Minnesota river, about a mile west of the county line. The swampy terrace-level which it there forms can be traced several miles eastward into Burnsville, and to sec. 19, Eagan, though no exposure of the beds appears in the Minnesota valley in Dakota county.

The presence of the Shakopee is frequently coincident with the existence of a shallow lake, or of a marsh, or a series of springs. This is noticeable not only in Dakota county but also in Scott and Rice counties, and indicates a rather compact and impervious formation, the upper portion of which seems to be a bed of shale.*

The St. Peter sandstone. This rock plays an important role in the topography and geology of the county. It operates precisely as in counties further southeast, but its arena of action here is so closely involved with the agency of other, and quite different, forces that several new features have resulted. These features, when studied by themselves, without a knowledge of all the causes concerned in their production, have been the source of various, and often divergent, hypothetical speculation.

It is evident from considerations which do not need to be mentioned, that the St. Peter sandstone, with its overlying shield and close companion, the Trenton limestone, once extended over the whole county and reached across the Mississippi and Cannon rivers, making an unbroken connection with the

* Compare the thirteenth annual report, p. 55.

Trenton areas of Wisconsin and with those of Rice county. The areas in which it is now wanting simply show where these strata have been eroded and carried away by drainage, first to the Mississippi and then to the ocean's bed whence they came. The areas in which they still exist have been more sheltered, or have been acted upon with less force by the denuding forces. The position and shapes of these relative areas indicate that the direction of abrasion was from the west and northwest. They are shown on the accompanying map, and the discussion of these abraiding agents is given under the head of *drift*.

In Dakota county the outcropping edge of the St. Peter sandstone is not so frequently seen as in some counties that have been described further southeast, but the topographic features which it produces are almost as sure an evidence of its presence as if the rock itself could be seen. This is specially true of the gravelly plains where it makes the boundaries of different prairie levels. It is also evident in the rolling till-covered areas in the northwestern parts of the county, but the great depth of the valleys there, their convergent trend toward the southeast and the outcropping of the formation in occasional spots along the Minnesota and Mississippi bluffs are sufficient to demonstrate its preservation under all the high hills of that part of the county.

Castle rock. The most interesting locality of this sand-rock is that which is well known as *castle rock*, situated in the town of Castle Rock, not far east of the centre of sec. 32. It was a landmark known by the Indians and early explorers. The Sioux Indians named it *Inyan bosndata* or standing rock, and, according to Mr. Nicollet, this name was applied by them to the Cannon river.* The term *Castle hill* was formerly applied to a similar outlier about twelve miles further northeast, its outlines "bearing the appearance of a dilapidated castle of feudal times." This is now known as Lone rock, and to the east of it a short distance is another which is generally designated Chimney rock. These are in secs. 14 and 13, Empire. The Inyan bosndata and the Castle hill are named on the large map of Mr. Nicollet, and the Chimney rock is also shown but not named.

Although Mr. Featherstonhaugh did not visit this spot, he has given the first known description and figure of the rock. His description is as follows:

Featherstonhaugh's description of Castle rock.

This pillar is situated on what is called the Big Prairie, and can be seen for a distance of twenty miles, somewhat resembling a church with a cupola; the lower part being a huge column, sixty feet

* The Dakota spelling of this is given *hiambouxecate*, in the Minnesota Historical Collections, vol. i, p. 326, and it is translated "river of flat rocks." See vol. i, p. 74, of this report.

high, and twenty-five feet in diameter; and the upper part being thirty feet in hight, and varying from two and a half to fifteen feet in diameter. This curious obelisk of sandstone is one of the proofs of the ancient continuity of strata, and of the general reduction which has taken place in the mineral structure of the country. For these particulars, as well as for the accompanying outline of Le Grand Grès, I am indebted to a traveler who had visited the locality and made a sketch of the pillar.*

FIG. 4. FEATHERSTONHAUGH'S VIEW OF CASTLE ROCK.

The foregoing statements of dimensions are nothing but exaggerated estimates by the traveler who furnished the drawing. About six years later, when Mr. Nicollet saw it, he made such measurements as to warrant him in stating its exact hight at thirty-six feet. In 1823 the party of major Long passed near this rock, but did not see it, their Indian guide being unwilling to take them there. Prof. Keating says the Indians named the Cannon river "Eamozindata (high rock), from a white pyramidal rock which rises to a considerable hight near this stream a few miles above the place where they crossed it."†

From the date of Nicollet's observation till 1872 there seems to have been no published reference to these outliers.

In the second annual report of the survey (1873) are figures that show this obelisk from three different directions, with various dimensions expressed, though it was described also in the first annual report. In June, 1883, this pillar was again examined. It had not noticeably changed. There were more carvings of names, etc., on it than ten years before, and the apparent certainty of its falling with the first blast of wind was more impressed on the beholder. A wagon road comes near it, and angles about its base on the southwest side. The farms round about are not fenced. It is an unfrequented tract, there being little or no reason to pass here except to make a visit to the rock. In

* Canoe voyage, vol. i, p. 290.

† Narrative of an expedition to the sources of the St. Peter's river, lake Winnepeek, lake of the Woods, etc., 1823, vol. i, p. 271.

the immediate vicinity of this rock the soil is quite sandy, the same extending about half a mile toward the southeast.

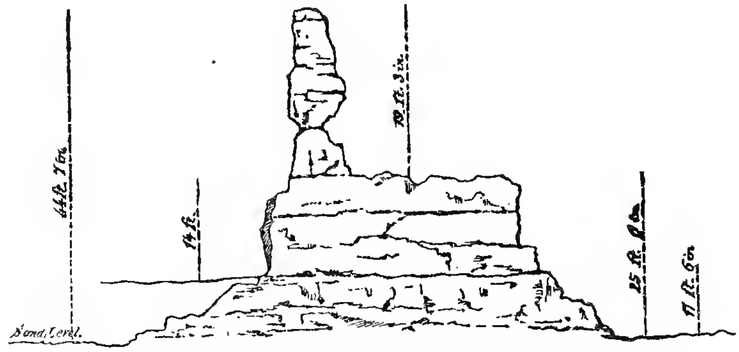


FIG. 5. VIEW OF CASTLE ROCK FROM THE WEST.

The base of the exposed rock is yellowish-rusty, but the pinnacle is white. A narrow streak of amethystine red sand crosses the body of the Castle about horizontally—at least it appears on the northwest side. Immediately below that the white sand is somewhat yellowish with iron-rust, for about three feet Another amethystine, or rather brick-red, band occurs between the white and the rusty sand at the base. On weathered surfaces are seen what appear to be fucoidal markings, and a porous, worm-eaten structure which has often been named *Scolithus.** The tubes of the latter are generally from one-eighth to one-fourth of an inch in diameter, and they are seen in nearly all parts bout thea base of this rock, especially on the northeast side. The following description, published in 1872, is applicable at the present time:

Description of Castle rock in 1872.

The singular pillar in Dakota county, known as Castle rock, consists of the St. Peter sandstone. It

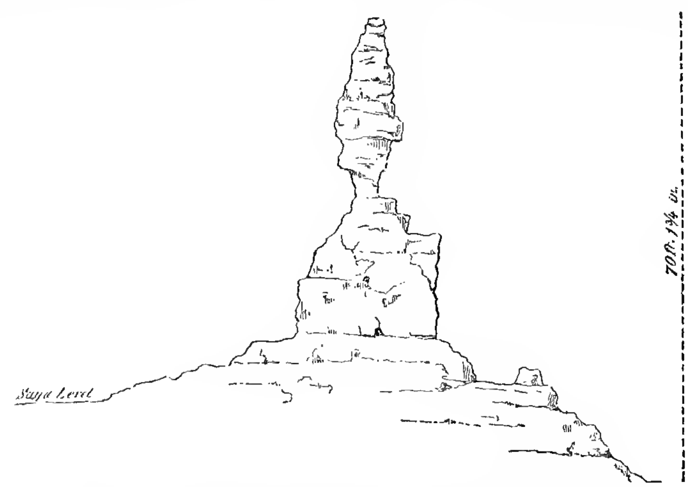


FIG. 6. VIEW OF CASTLE ROCK FROM THE SOUTH.

stands on the arch of the local anticlinal axis from which the beds dip gently both toward the north and toward the south, and is an outlier from which most of the formation has been removed over an area of

* Compare vol. i, p. 656. The same tubular openings are visible in the St. Peter along the south line of sec. 28, Wateforrd.

some miles about. Its form is that of a somewhat regular right prism, or parallelopipedon elongated north and south, supporting on its northern end a pinnacle of bedded sandstone about four feet in diameter at the base which rises above the general mass nineteen feet and three inches. A view from the west shows, of rock, forty-four feet and nine inches, rising above the general surface of the sandy mound on which it stands. Rock can be seen on the east side about twenty feet lower than on the west. A depression along the east side of the outlier is twenty-six feet below the lowest rock visible. From

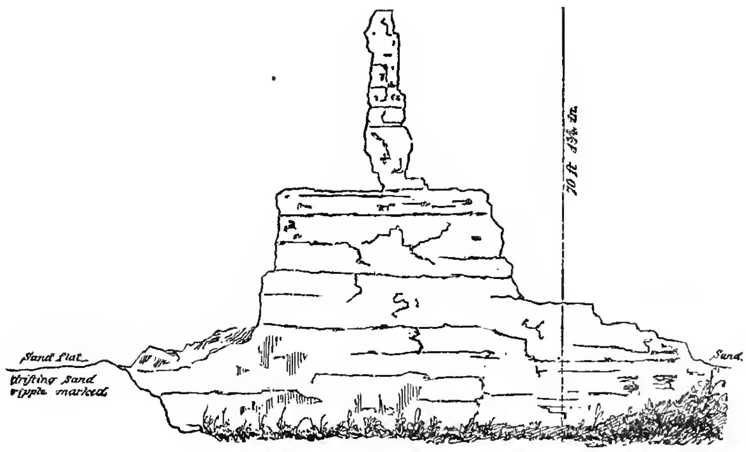


FIG. 7. VIEW OF CASTLE ROCK FROM THE SOUTHEAST.

the bottom of this depression to the top of the tower is seventy feet one and three-fourths inches The irregularly ascending base visible from the west is eleven feet six inches. The perpendicular sides of the general mass of the rock are fourteen feet, and the tower is nineteen feet three inches. Near the base of the tower is a somewhat argillaceous layer, or one less firmly cemented, of a few inches, which weathers away faster than the rest, making the diameter there considerably less than above. Hence the tower has a threatening aspect, and the first impression of the beholder is the certainty that the first severe blast of wind will throw it from its place. The mass of the whole is separated perpendicularly by a number of divisional planes that also may be seen entering the rock below the castle. These pass in a direction northeast and southwest, and have so aided the attacks of the elements, and invited the ambitious, but sacrilegious, carvings of visitors that a hole has been made through the body of the rock.*

An outlier of the St. Peter sandstone, situated in sec. 14, Empire, is known as Lone-rock, owing to its rising in the midst of a prairie and forming a very conspicuous object for a great many miles in all directions. From its summit, which is about a hundred feet higher than the surrounding prairie, can be seen toward the east the crests of several other outliers of the same stone within a mile or two, one of which is known as Chimney rock, while still further east the eye looks upon the bluffs of the opposite side of the Mississippi. Toward the south the valley of the Vermilion spreads out in a broad basin. Farmington village is situated to the southwest, and the spacious grain-elevator at the station of Rosemount is a con-

* First annual report, p. 91.

spicuous object toward the northwest. The country immediately surrounding is a treeless prairie, for the most part a level. In the midst of this flat these knobs of the St. Peter rise, forming knolls on which, when sufficiently turfed, two or three species of oak and a variety of shrubs maintain a stunted growth. Near the north end of the rock the strata show a marked dip toward the south, besides irregularities of sedimentation that greatly resemble dip. The rock rises in the form of an interrupted ridge running north and south, and extends about twenty-five rods. The hight from the surface of the water standing in a little excavation on the northern flank of the bluff, to the base of the bare rock, is about twelve feet. From the lowest rock seen to the top of the ridge is about forty-one feet. There are indications on the top of the rock that the formation did not extend much higher. The grains are coarser, and the limy cement is more abundant. The weather has also caused it near the top to show thin beds of one-half to one and a half inches. The entire width is about twenty feet at the northern end, but it tapers rapidly to two or three feet. Then it swells out in a sort of zig-zag ridge, and after one or two interruptions it disappears under turf on which grow shrubby oaks. The southern extremity is rocky again, like the northern. The dip mentioned shows only at the northern extremity. In the valleys about, the drift prevails and boulders may be seen. Two other knolls of St. Peter sandstone, besides the Chimney rock,* are in Vermilion, one in sec. 18, and one in sec. 8. These, however, are not yet reduced to so barren and pinnacled a stage of disintegration.

It will be noticed that these outliers lie approximately in a line parallel with the great fault that has been mentioned, and all on the northern side of it, *i. e.*, on the up-thrown side.

A great many ridges and knolls, large and small, lying between the Vermilion river and the Cannon, contain the St. Peter sandstone. Some of these extend east and west a distance of eight or ten miles, but they are generally capped by a few feet of beds of the Trenton limestone. Within the valleys also isolated knolls of the St. Peter exist. These are of all sizes and hights, from the merest undulation to abrupt and even rocky hills. Sometimes the sandrock is white and crumbling, and sometimes it is in hardened, detached blocks. These knolls are apt to be overstrewn with drift boulders, there being

* Mr. Upham has also noted a "Chimney rock" in the N. E. ¼ of sec. 31, Marshan, turret-like, with vertical or over-hanging sides.

none visible elsewhere. On the westerly angles of these hills the winds have kept the rock bare, and there they are frequently craggy and perpendicular.

Toward the west further, as the drift increases in thickness, outcrops of this rock become fewer and fewer. It underlies all the high land, whether prairie or woodland, all the way to the Minnesota; and much of the roughness of surface through Lakeville, Burnsville and Eagan can be attributed to the gorged condition of the Trenton and St. Peter.

There is a weathered sandy knoll of this sandrock in Eureka township, near the center of sec. 22. The surface is white, with no soil, presenting a singular contrast with universal green of the surrounding nearly level prairie. A few boulders still lie on it.

As the Trenton exists in sec. 23, Burnsville, where it is quarried, the surrounding valleys, particularly those extending northeastward from there, must be wrought in the St. Peter sandstone.

The St. Peter appears in the bottom-land of the Minnesota river on the S. W. ¼ of sec. 33, Mendota, where it forms a small island which sometimes is nearly covered by the water of the river. The rock lies in heavy layers nearly horizontal, but dipping a little to the west of south. This island is about half a mile from the dry land of the right bank of the river, and rises ordinarily about fifteen feet above the water. It is about a fourth of a mile in length, and has a few small oaks scattered over it. It can be reached only on the ice in winter, or by boat in summer. This rock here has been somewhat quarried, and furnishes a very good stone for bridge-piers. It has been used in the bridges at Fort Snelling. It presents every shade of color resulting from iron and manganese deposited by evaporating water, from the yellowish stain which comes at first over a white sand, to brick-red and umber-brown, the most of it being of a pleasant rusty yellow.*

The deep well at Hastings. As the foregoing strata all pertain to the Cambrian, the record of the deep well sunk at Hastings by the Chicago, Milwaukee and St. Paul railway company would be appropriate at this place, as it passes only through Cambrian strata. It is located at the depot, near the river, and begins seven hundred and ten feet above the sea, and ninety feet below the top of the Lower Magnesian limestone as exhibited in the bluffs of the Vermilion river adjoining. The water flows from the surface at the rate

* Final report, vol. i, p. 177.

of about one hundred gallons per minute. It will rise fourteen feet above the top of the tube when confined. It is as follows:

1.	Dolomitic limerock, *Lower Magnesian*,		80 feet.
2.	Sandrock,	*Jordan*, 122 feet.	15 feet.
3.	Dolomitic grit,		12 feet.
4.	Sandrock, supplying no water, [Some of this is coarse and some is fine. In the lowest ten feet the drillings contained fragments and rusty tubes that recall the tubes in the St Peter sandstone described in vol. 1, p. 656, but these are much firmer.		95 feet.
5.	Sandy shale, white, mostly sand,	*Mendota*, 213 feet.	25 feet.
6.	Gray shale, with much sand and some dolomite, *St. Lawrence.*		43 feet.
7.	Green shale, i. e. sand and green sand,		20 feet.
8.	Green shale, probably pulverized green sand,		110 feet.
9.	Sandy shale, sand and green sand,		15 feet.
	[Nos. 6, 7, 8 and 9 may all be described as sand and green sand.]		
10.	Sandrock with a few lumps of iron pyrite,	*Dresbach sandrock.* 80 feet.	20 feet.
11.	Sandrock with a few lumps of iron pyrite,		20 feet.
12.	Sandrock with more iron pyrite; first flow of water,		20 feet.
13.	Gray, sandy shale,		20 feet.
14.	Blue shale,	*Dresbach shale.* 95 feet.	70 feet.
15.	Sand and pulverized green sand,		20 feet.
16.	Dolomitic grit with gray shale and sand,		5 feet.
17.	Sand rock with lumps of iron pyrite and dolomitic grit. Second flow of water,	*Potsdam sandstone?* 230 feet.	5 feet.
18.	Sandrock with some pyrite,		25 feet.
19.	Sandrock, coarse,		10 feet.
20.	Sandrock,		10 feet.
21.	Sandrock, coarse,		10 feet.
22.	Sandrock,		100 feet.
23.	Sandrock, coarse,		30 feet.
24.	Sandrock, fine and coarse, some grains one-quarter inch in diameter, one of black quartzyte, with traces of red shale,		40 feet.
25.	White quartz sand mixed with pinkish, apparently orthoclase sand, and some grains of red and black quartzyte,	340 feet.	30 feet.
26.	Red shale, with some white quartz sand,		20 feet.
27.	Red and white sand with pieces of battered metallic iron, doubtless from the drill,		15 feet.
28.	Red shale,		40 feet.
29.	Mainly white quartz sand, but tinted red by bits of shale and other red grains; contains bits of metallic iron,		75 feet.
30.	The same but more red,		50 feet.
31.	The same; the shale is soft and has a red powder, like hematite,		110 feet.
	Total depth,		1160 feet.

The Trenton rocks form the protecting mantle for the St. Peter sandstone in nearly all parts of the county where the St. Peter is known to exist, constituting the crest of the terrace-level that is marked off distinctly from the lower levels in Rosemount Vermilion, Hampton, Randolph, Castle Rock, Eureka, Lakeville and Lebanon. It also underlies the rolling land, characterized by a morainic till surface, in Burnsville, Eagan, Mendota, West St. Paul and Inver Grove.

In these till-covered towns it is also quite probable that some of the higher strata, which consist largely of shale, remain intact under the drift. In corresponding levels in Ramsey county such shaly beds are known to exist.

The most frequent form of outcrop for the Trenton rocks is seen in the upper slopes of the hills and long ridges in Randolph, Hampton and Vermilion. A few feet of thin, weathered, limestone strata may be seen forming a persistent brow or interrupted escarpment near the top. These have attracted the attention of the quarryman and have furnished great quantities of useful bluish-gray or yellowish, dirty-gray, limestone slabs for foundations for farm-houses, and for bridge-piers throughout this part of the county. These quarried beds seldom afford a thickness of more than twelve feet, though on the working of the quarry, some higher layers, less firm and generally valuless, are found to overlie the quarry-stone. Immediately below these quarries, generally along the roadway in which the stone is hauled to the plains below, the St. Peter sandstone is found in outcrop, and supplies the sand needed for the mortar in the same wall. The beds of the quarry are sometimes slightly disturbed and displaced, owing to the long exposure, and the slight drift covering, and to the fact that the underlying sandstone has been eroded so as to remove their support.

The quarries of Timothy Haynes and Wm. Rice, near Hamilton, are near the middle of sec. 23, Burnsville, in high bluffs on a level with the undulating terrace at Berrisford, and seem to indicate that the same layers exist in that terrace. They furnish a useful stone, but one which is not yet appreciated by the residents in that part of the county, and the quarries are feebly sustained.

Anun Torgerson has a quarry in the Trenton near the centre of sec. 27, Eureka. The stone is all affected by decay and is yellowish throughout, the bedding being separated by rust scales and limy incrustations. Over the stone is a rotted pebbly till, or pebbly clay, six feet thick, containing some stones two or three inches in diameter. The quarrying has brought to light some boulders, some of them being of the "Winnipeg limestone." In these are species of coral, apparently *Favosites* and *Stromatopora*. The bedding seen is only about four feet, lying about thirty feet lower than the land immediately adjoining at the south. The same beds strike across the road just north of the school-house, and below them, a little further north, the St. Peter sandstone is also exposed.

There are quarries in the Trenton at the top of the bluff near the east line of sec. 24, Sciota, owned by T. Denny and Charles Meggs.

Jos. Batson has a good, quarry, sec. 26, Castle Rock. Al. Martin's and several others are in the same vicinity.

Mr. Garvey owns a quarry in the Trenton, S. W. ¼ of sec. 7, Empire, which supplies a great deal of stone. It sells at the quarry for five, and five and a half dollars per cord of one hundred and twenty-eight cubic feet. The drift overlying is red till. This quarry is in the slope from the upper to the lower prairie, and shows that the valley running across the northeast corner of Lakeville is cut in the St. Peter sandstone.

Wm. Fall's qnarry is on the section line between 13 and 24, Castle Rock.

Mr. M. D. Green has a good and much worked quarry in the Trenton in the S. E. ¼ of sec. 22, Castle Rock. Mr. Roder's is on the same quarter-section, next southeast from Mr. Green's.

Daniel F. Aiken's quarry is a mile and a half northwest from Farmington, on sec. 24, Lakeville.

The full thickness of the exposed strata here is about seventeen feet, showing considerable disturbance by being undermined.

There are several quarries at West St. Paul, but they are in Ramsey county.

The Cretaceous. In 1873 a small outcrop of bluish shale, more or less resembling clay, was seen near the highway bridge over the Vermilion, on the west side of sec. 24, Empire. This was then presumed to be Cretaceous shale.* It was so broken, and mingled with the drift, being near the traveled descent to the fording place of the river, that no satisfactory description could be given of it.

But little further evidence of the Cretaceous in this part of the state has been discovered since then. It is to be presumed that the Cretaceous beds once covered the county, since they are in such force in Goodhue county, next south of Dakota. Still, it is possible that all the following facts, as well as the foregoing, may be accounted for by referrring them to the gray boulder-clay, which contains, nearly everywhere, some traces of Cretaceous rock.

Judge T. O'Leary, of Hastings, reported, in 1878, that in a well in Vermilion, sec. ? at the depth of one hundred and ten feet beneath the surface, were obtained Cretaceous fossils. These on examination were found to be samples of woody lignite, and of *Belemnites*. Pieces of fossilwood are occasionally found in the central and western parts of the county, one such apparently from the gray till having been brought up from the depth of about 100 feet in digging a well on sec. 8, Lakeville.

THE DRIFT.

The drift-deposits of the county, and their distribution, will be described and understood best by reversing the inductive method, and announcing the conclusion first, *viz.:* Two glacial periods have operated in Dakota county, each one leaving its traces in the form of moraine, till-sheet, and modified drift. The effect of the first, which extended furthest east, was over-wrought and largely effaced by the second. They were separated by a long interval of time, and during that interval the forces of atmospheric precipitation and surface drainage acted only on the first sheet of drift. During the prevalence of the second the powerful action of the ice-and-gravel-laden waters on that part of the county which was not reached by the moving ice of the glacier was sufficient to excavate broad valleys both in the drift before deposited and in the erosible rock-beds, and to spread extensive plains of gravel. But its chief influence was in screening the characters and actual extent of the older drift by working it over, mixing it with the newer and burying the whole under copious deposits of water-worn gravel and sand. Such hills as Castle rock lie outside of the action of the ice of the last glacial epoch, but yet within the action of that of the first. When the first ice-sheet covered the county, coming mainly from the northwest, it extended as far east as the till-mounds in Marshan, and the rock area at Castle rock must have been much larger than it is now. It received the action of the ice of that epoch, but was still left as a large Trenton mound. After the interglacial age had passed, and the second

* Second annual report, p. 177. Since the report on Rice county was published Mr. Joseph Goar has reported facts that indicate a large area of Cretaceous south of Morristown, in that county.

epoch advanced, its area was reduced, along with that of all other similar mounds, by the waters that accompanied that epoch. The St. Peter sandstone was undermined. The Trenton slabs fell from their positions and mingled with the drift and boulders which they before supported, and with the newly spread gravel and sand, the mound was entirely uncapped, the limestone dissolved and disappeared, the sandstone was indurated by exposure and has maintained a struggling existence till the present time. This succession of changes can be predicated of all the "mounds" and "castles" in the eastern part of the county in various stages of advancement, since they all happen to be between the margins of the two ice-sheets. It was the fortuitous conjunction of the arena of this double drift-action with the strike of the Trenton and the St. Peter that brought out these features prominently in Dakota county; though the changes here described and the causes that produced them, are all concerned in producing the topography of several other counties in southeastern Minnesota, and have been mentioned in other chapters.

Till areas. The areas of the older till are found on the highlands in that part of the county east of the morainic belt of the last glacial epoch. In the lower levels it is either washed out or is covered by the gravel and sand derived from the later epoch. This older till is blue, and was derived therefore largly from the northwest. The singular mounds in sec. 1, Marshan, are composed of such gray till. It also is found in the northern part of Vermilion, Empire and Lakeville. It covers the eastern part of Eureka, blending toward the west with the gray till of the last glacial epoch. It occupies the broad belt of Trenton highland that runs about east and west from Chub lake, in Eureka, to the northern part of Douglass. It is found under the surface materials in Greenvale, Waterford, Sciota and Randolph.

The later gray till is typically exhibited in southern Greenvale, northwestern Eureka, the timbered part of Lakeville and Burnsville. It has a confused and super-posed line of junction with the red till in northern Burnsville and western Eagan.

The red till is spread over the most of Eagan, the whole of Lebanon, northern Rosemount, Inver Grove, Mendota and West St. Paul. There are many places, however, where the red till is mainly composed of gravel and sand with numerous large boulders, the contour being very rough.

The till areas that appertain to the moraine of the last glacial epoch are characterized by many lakes. These lie in deep depressions, the hills surrounding being sometimes over a hundred feet above their surfaces. In the areas of red till these depressions are deeper and steeper than in those of gray till, and the hills are more likely to consist largely of gravel and sand.

The older gray till forms its most important appearance in the mounds in sec. 1, Marshan. It consists of an irregular group of hills rising about one hundred feet above the surrounding plain, with the characteristic pose of a terminal moraine. This moraine, if such it be, may be supposed to spread northwestwardly, underlying the elevation that is seen in secs. 34 and 35, Hastings, as well as that in the northeastern part of Nininger township, whence its continuation northward lies probably in Washington county. The mounds themselves consist essentially of pebbly and stony till, as revealed by wells that have been sunk into them to the depth of a hundred feet. The smaller mound, which lies southwest from the main hill, is round at the base and rises evenly, like a cone, to a rounded apex, eighty-eight feet above the plain. Pebbles are strewn over the surface; and on the top, which is evenly rounded over, and perhaps fifteen feet across, the surface is completely covered with coarse gravel stones of northeastern origin, among which are many of brown-red, metamorphic shale and quartzyte as well as brown amygdoloid. There are also many of greenish-blue, fine, diabase, and of white quartz, and an occasional one of coarse, gray syenite, and of dioryte. On the slopes — along the ravine separating the small mound from the large one — are several large diabase boulders. At a distance, by a person who has not made a closer inspection, these hills would be taken for some outlier of the St. Peter and Trenton, like those further west. There is no sign of any similar deposit anywhere else, toward the south or east, but toward the north the same kind of a deposit constitutes, outwardly, the lower hills that lie along the south side of the Vermilion river near the Falls of the Vermilion.

In Douglass and Marshan, in general, those surfaces above eight hundred feet are likely to be of till, those below of gravel and sand, but even the till surfaces often have a sandy and gravelly covering.

There is a large area of till in the S. E. corner of Marshan, and the most of the town of Douglass is high and undulating, underlain by the Lower Magnesian, with a thin layer of old drift. The immediate surface is composed of the yellow loam, similar to that on the highlands in northern Nininger, but it becomes gravelly, as well as stony, in those places where some ready supply of stones is present, as the old till, or the Lower Magnesian.

The worked-over surface of this old gray till is seen in numerous places in the central part of the county, as already mentioned. It is seen in the immediate vicinity of Castle rock, and between the obelisk and Castle Rock station.

The later gray till is more rough in its outline. It is seldom covered by a fine stratified loam, and it is naturally timbered. Its eastern margin lies over the older gray till in Greenvale, Eureka and Lakeville townships, but in the central part of Burnsville it is confusedly blended with the red till of the later glacial epoch. The eastern part of Burnsville is covered with red till, but this red till has below it, in some places, a blue till which, theoretically, is of the age of the older glacial epoch, but may be of the later. Along the north side of Crystal lake a gray till occupies the higher positions, but at a mile from the lake, northward, the high land consists of a sandy, red, and stony till. Along the river-road the till changes from gray to red in sec. 35, Burnsville, but again to gray in sec. 19, Eagan. Thence to sec. 4, the road through Black Dog* passes through a rolling tract of gray till, the hills being from fifty to a hundred feet above the valleys. No gravel terrace, in general, is here visible, the rolling surface apparently breaking it up. The most notable thing here is the thick, yellow loam, through which stands up occasionally a large gray granite boulder, as on the prairies. Indian and Buck hills, the former near the west end of Lakeville lake and the latter near the west end of Crystal lake, rising about eleven hundred fect above the sea, are prominent and characteristic hills of gray till. Other similar hills are in the same vicinity. These have the notoriety of having been distinctively named, because of their conspicuous and bold appearance. Buck hill is a short, sharp, isolated peak, turfed all over with the usual prairie grasses, asters and amorpha, and by aneroid barometer rises about two hundred and fifteen feet above Crystal lake. From this hill can be seen the city of Minneapolis.

On the S. W. ¼ of sec. 19, Eagan, there is a succession of gray, morainic ridges rising above each other toward the east, along the west side of which, at a lower level, is a gravel terrace. The adjoined diagram shows a profile of the bluffs at this place.

* Among the inhabitants of the western part of the county this name is still applied to the region of the old Indian village, *Tetankatane*.

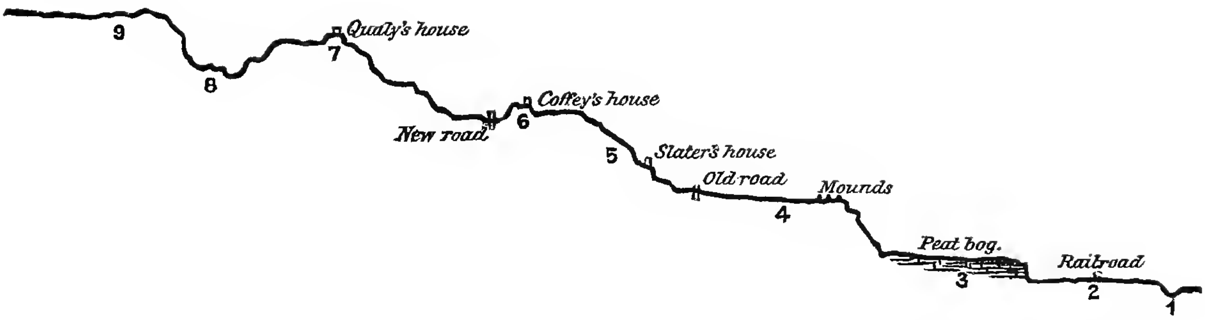


FIG. 8. PROFILE OF THE EAST BLUFF OF THE MINNESOTA RIVER, SECTION 19, EAGAN.

EXPLANATION OF FIGURE 8.

1. River level, about six hundred and ninety-five feet above the sea.
2. Meadow and lake, about seven hundred and fifteen feet above the sea, flooded at the high stage of the river.
3. The Shakopee terrace, covered with a peat bog, about seven hundred and thirty-three feet above the sea. This terrace, as at Hamilton, and numerous other places observed, is marked by a course of springs which it causes, accompanied by impassable bogs, also with bog-ore and marl. The peat here is from five to six feet thick, and of good quality.
4. Gravel terrace (sandy-loam-covered), about eight hundred and thirteen feet above the sea, with artificial mounds. The west margin of this terrace is about eight hundred feet above the sea, and the east margin rises sometimes to eight hundred and fifty feet.
5. Gray till-terrace, rising to about eight hundred and ninety-five feet above the sea, covered by yellow, clayey loam; undulating and rather broken, rising to Qualy's house, a little further south.
9. Loamy undulating surface over which the new road runs near Coffey's house.
7. Gravelly summit of the gray moraine, nine hundred and seventy feet above the sea.
8. Wooded valley.
9. Light sandy hills, appertaining to the red till moraine, about one thousand feet above the sea.

The red till cannot be separated, as to age, so certainly into two parts. This is not due so much to the known absence of red till of the former glacial epoch, from the county, as to the ease with which it is overwrought and its characters lost in those of the gray. It is not now possible to assert that any deposit of red till is known in the county that can be referred to the earlier epoch, though numerous stones that must have been formerly embraced in the red till are found scattered through the gravelly knolls that occur in the central towns. The later red till, from the north and northeast, furnished a characteristic red gravel and sand, and this is spread over the eastern plains, and mingles with the gravel derived from the gray till.

It is true, still, that on the evidence of the gray till mounds in eastern Marshan, that are apparently on the extreme eastern limits of the gray till moraine of the earlier epoch, it is not reasonable to expect to find a sheet of the older red till in Dakota county. The gray till only could have been deposited in Dakota county. Further examination, however, directed to this point specially, extended across the Mississippi into Pierce county, Wisconsin, is needed in order to establish the mutual limits of the red and gray tills of the earlier epoch.

The red till of the later epoch is spread characteristically over the northern part of Rosemount, Inver Grove, West St. Paul, Mendota, the eastern two-thirds of Eagan, Lebanon, and the southeastern part of Burnsville. It is the drift that constitutes the highest hills and ridges in this part of the county. Although here it is all spoken of as till, yet it cannot be all included under that term. It is largely composed of gravel and sand; and it is a remarkable fact that the summits of the highest hills, such as those in southern Eagan and northern Lebanon, where this red drift prevails, are composed of sand, or a sandy loam, so light and so dry that they are barren, or support only the scant vegetation comprised in a tufted, short grass, red sorrel, occasional mulleins, avens, thistles and a few golden rods and asters. In other places a scanty turf covers the surface and a few shrubby trees of burr oak barely live.

The town of West St. Paul, along the "German road," is high and rolling with red till. The highest land is along the west side of the road, and rises at least a hundred feet higher than the road. The elevations along the road are from seventy-five feet to one hundred and twenty-five feet above the depressions, many of the latter containing lakes. At about the crossing of the boundary between West St. Paul and Inver Grove, there is a perceptible change in the nature of the drift. It becomes more and more sandy and gravelly. No lakes are in the depressions, the looseness of the gravel allowing the water to drain away, and wells penetrate only gravel and sand to the depth of a hundred feet, often finding no water. Yet there are occasional clayey places, located without any known order, some of which afford water within a few feet.

The line of junction of the red till with the gray is in Burnsville and Eagan. The later gray till lies on the later red, but the latter lies on the older gray. The western limit of the red till may be approximately defined as follows: beginning at the southern side of sec. 5, in Lakeville, it passes across the eastern end of Crystal lake, to the N. E. ¼ of sec. 31, in Burnsville, thence northwesterly, through the centre of sec. 25, northerly through the centre of sec. 24, into the S. W. corner of sec. 18, northerly into the the S. W. corner of sec. 35, to the centre of sec. 25, easterly through sec. 30, Eagan, thence in irregular patches through secs. 29, the N. W. ¼ of sec. 28, to the centre of sec. 16, through the east side of sec. 9, and of sec. 4, and thence across the Minnesota river into Hennepin county. There is also an isolated area of red till in southwestern Eureka, about Chub lake, the extent of which is not certainly known.

Gravel plains and ancient water courses. The Vermilion and Cannon rivers are the shrunken remnants of once powerful streams. Some of their former tributaries are now dry valleys. The period of their greatness vanished with the ice of the last glacial epoch. The proofs and the consequences of their power consist of terraced plains and rich valleys that penetrate the moraines of the northwestern part of the county. The history of the Cannon valley in its course through Rice county has been detailed briefly in the last chapter of volume one of this report, and it will be best to resume the description of that stream at this place.

The Cannon valley, as shown in the report on Rice county, once was swollen by the waters of the Minnesota. At that time it spread over the flat prairies of Waterford, Sciota and Randolph, laying down the gravel and sand that constitute their sub-soil. It was augmented by the water of Chub creek which, at the same time, spread a similar deposit over the northeastern part of Greenvale, carrying off the drainage supply from the melting ice in eastern Rice and Scott counties, as well as from the region of Chub lake, in Eureka. The level of the surface of the river, which was then more like a lake than a river in its extent, was above the level of the highest gravel terrace, the gravel terrace indicating the then bottom of the river. At Northfield the highest gravel deposits are about nine hundred and eighty feet above the sea, or about eighty feet above the water in the river. About Cannon Falls they are about ninety feet above the river. It is probable that at this stage of the river some of its waters passed northeastwardly across southern Hampton and Douglass and reached the Mississippi, likewise swollen so as to spread over the plains south of Hastings, in the vicinity of Etter. The bluffs at Hungry point, N. W. ¼ of sec. 1, Ravenna, enclosing a valley cut in the Lower Magnesian limestone tributary to the valley of Etter, are low, and present the appearance of having been long submerged and washed, so that they are shattered and degraded. The Trenton mounds in Randolph were islands in the river. The Shakopee limestone was buried under a uniform sheet of gravel and sand all the way from Waterford to Cannon Falls. As the river was reduced in volume it selected its present narrower valley, and excavated in the loose materials its present bed, only occasionally revealing, even to the present, the underlying rock. The present outline of the natural surface is indicated by the following diagram which runs from the mound in sec. 3, Randolph, southwestwardly to the river. Chub creek, in secs. 16, 17 and 18, Greenvale, runs through extensive marshes; and about these marshes is a terraced plain about forty-five feet above them, consisting of gray gravel and sand.

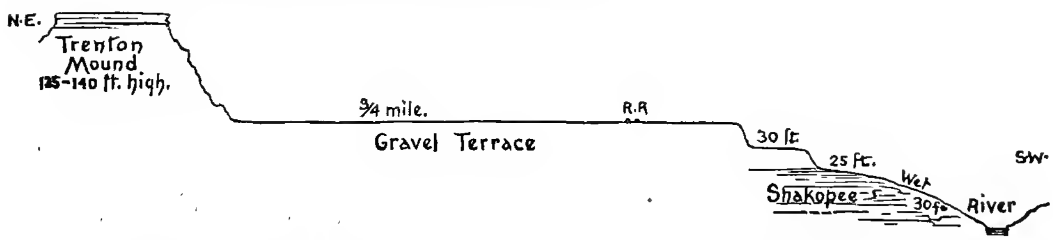


FIG. 9. DIAGRAM OF THE NATURAL SURFACE ON SEC. 10 RANDOLPH.

Gravel plains of the Vermilion river. At the same time that the Cannon valley was thus flooded, the Vermilion was pouring a muddy stream into the Mississippi at and below Hastings. This water was the result of the local thawing of the margin of the ice in the immediate vicinity of its sources but at a later date this river was vastly increased by the waters that came from the Minnesota. It is not certain that the Minnesota was so dammed by the ice that all its water was carried away by the valleys that cross the county and empty into the Vermilion, but it is very evident that a large amount of water passed through the gaps in the moraine which lie in eastern Scott county and northwestern Dakota. The most western source of the Vermilion reaches into New Market, in Scott county, and enters Dakota county in sec. 18, Eureka. It closely inosculates with the upper tributaries of Credit river and may have served as an avenue of partial discharge from the glacial lake of the Minnesota valley at a slightly later date than the Cannon valley. This, however, has not been fully ascertained. Where this stream enters Dakota county its water-level is less than a thousand feet above the sea, and it occupies a wide marshy valley. According to Mr. Upham there are evidences of standing water traceable in the drift-deposits of Scott county in the western part of New Market, at levels sufficiently high to have allowed the discharge of water from the Credit valley across the divide into the Vermilion river, through Eureka. The "big slough" in the northern part of Castle Rock must then have been the main passage-way for this flood, and some of it found its way to the Cannon valley through the gravel-strewn valley passing through the village of New Trier into Trout brook, in Douglass.

There are two other continuous channels, now dry, which show a direct connection of the Minnesota river with the Vermilion river and the plains of central Dakota county, showing not only that when the ice prevailed the Vermilion was a flooded glacial stream but also that at a still later stage it shared in the abundant waters of the Minnesota. One of these passes through southern Burnsville to Crystal lake, and its bottom is known as the "lower prairie," in Lebanon and Lakeville, having an elevation about nine hundred feet above the sea. The other is known as the Rich valley, running from near Mendota to the northeastern part of Rosemount.* These gravel-strewn, wide valleys, are terraced distinctly all the way from where they begin, to the Mississippi. The terraces widen out in the central towns of the county and constitute the "big prairie," so called, in distinction from the "big woods," these plains descending gently toward the east and uniting with the gravel terraces of the Mississippi.

The Crystal lake channel

The divide between the Minnesota and Crystal lake, rises about eight hundred and fifty feet above the sea, and consists of drift, the enclosing bluffs being of gray till with considerable foreign limestone, and having treeless, stony surfaces. In the valley between Hamilton and Crystal lake are several marshes and small lakes. On the west side of the divide the till surfaces are covered with a loam of a a light-yellowish, or ashen, color found to accompany the gray till rather than the red. The highest gravel terrace accompanying the valley west of Crystal lake is a little less than nine hundred feet above tide, or one hundred and eighty feet above low water in the Minnesota at Hamilton, or about forty feet above Crystal lake, constituting, in its eastward extension, the "lower prairie," in Lebanon and Lakeville. Between the bluffs of this terrace near the county line, there is a low drainage valley at the present time, with occasional marshes, carrying but little water. The bottom of this is about fifty feet lower than the terrace level. This terrace flat spreads largely into Scott county west of the county line, south from Hamilton. Crystal lake is about eight hundred and sixty feet above the sea, or about forty feet below the "lower prairie." It was formerly, since settlement, six or eight feet higher. It has no visible outlet, but sinks away through the sand.

The Rich valley channel.

The other continuous glacial-water channel tributary to the valley of the Vermilion begins about a mile and a half south from Mendota and ends in northeastern Rosemount. It spread its gravel debris like alluvial fans over the plains southward and southeastward, at a level somewhat higher than the present level of that stream, on the north side of the Vermilion, from Empire to Hastings, even uniting with the Cannon in covering the towns of Marshan and Ravenna with the relics of its floods. The connection of this valley with that of the Minnesota is not so marked as that of the Crystal lake channel. Its northwestern end is broken up into a rolling and gravelly surface with irregular depressions, sometimes

* The valley running southeastwardly from Prairie lake, in Lakeville, is entirely analagous to that from Crystal lake and seems to have served formerly a similar purpose in the drainage of the glacial epoch.

having lakes and sometimes not. In the northeastern part of Egan, it is divided into two branches, the easterly branch extending nearly north and reaching the Mississippi about a mile and a half east of Mendota. Each of these branches is about a mile wide. The bottom of this transverse valley, at the summit separating the present drainage into northward and south-flowing streams, is about one hundred and thirty feet above low water at Mendota, and hence about eight hundred and fifteen feet above the sea. This summit is in sec. 25, Mendota, in the easterly branch of this channel, where a long, narrow marsh drains northward by a constant creek, reaching the Mississippi about a mile below Mendota. In the westerly branch the divide is not noticeable, but it is apparently in sec. 1, Eagan, near the point of union with the easterly branch.

Gravel and sand, often in broad plains and terraces, characterize this old channel. In the northeastern part of Eagan the westerly channel is separated into two parts by an island-like plateau of modified drift which has an elevation of about nine hundred feet, and in the eastern sub-channel the modified drift is disposed in the form of kames that run southeasterly and can be traced about a mile. There are two parallel ridges and some subordinate kame-like ridges.

Gravel terraces of the Minnesota valley.

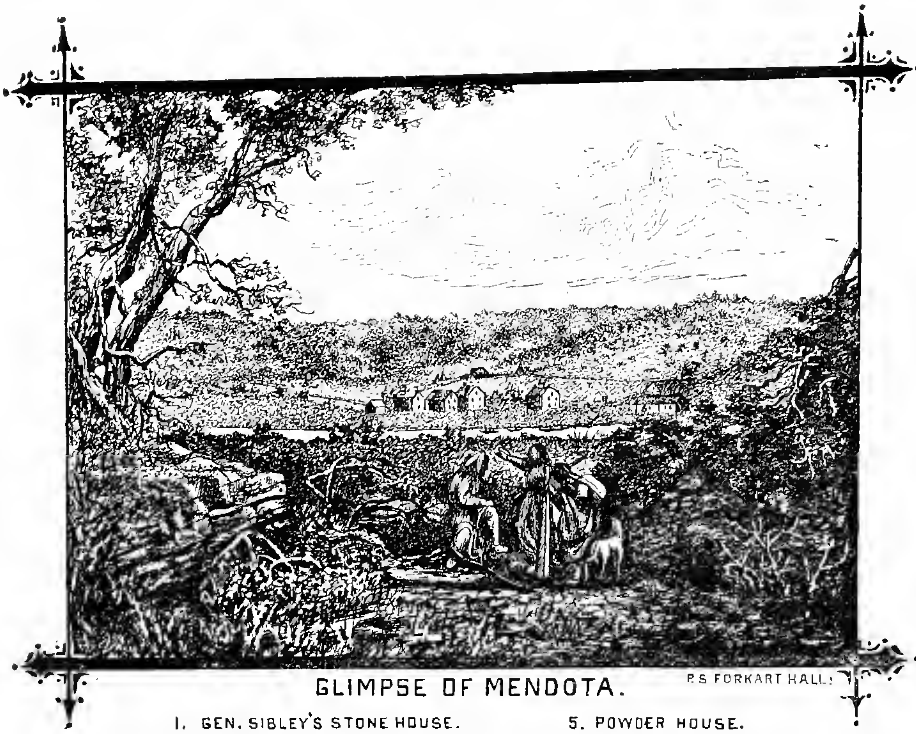
Between Hamilton and Mendota are conspicuous terraces of gray gravel and sand. These sometimes lie on the gray till and sometimes on the red. In some places they are wanting, and the gray till, with its bare surface and irregular outline, presents its morainic margin in the river bluffs. South and east from Hamilton is a conspicuous terrace which extends into Dakota county. At the county line it is about eighty-five feet above the depot at Hamilton, or eight hundred feet above the sea. This terrace, which at the county line is about an eighth of a mile wide, descends gradually and widens toward the east and its composition changes from coarse, rolled gravel and sand to yellow loam, and on the N. W. ¼ sec. 13, Burnsville, it is from forty to fifty feet above the west meadows of the flood-plain, or from sixty to seventy feet above low water. Further east, in sec. 34, the terrace flat is broken by the projection above its upper surface of knolls of gray till, which increase in hight irregularly and in some places blend with the rolling upland surface, the gravel plain surrounding these knolls having an elevation of about eight hundred and twenty-five feet above the sea.

Still further east, in sec. 35, Burnsville, west of Walter Connolley's, the terrace becomes conspicuous, and thus continues to near Nicols station, with a width from a quarter to a half mile. The surface of this terrace is a sandy loam, and on it are extensive and valuable farms. In sec. 19, Eagan, it is about one hundred and twenty-five feet above the river, or eight hundred and twenty feet above the sea. From Nicols station, through secs. 9, and the southern part of 4, there is left no evident trace of this gravel terrace; but only a rolling surface covered with a copious yellow loam.

In sec. 34, Mendota, is a terrace about half a mile wide uniting with that which marks the old valley extending southeastward, having an undulating upper outline which averages about eight hundred and fifty feet above the sea. This lies on, and apparently blends with, the red till along its upper edge.

In N. E. ¼ sec. 4, Eagan, the river road runs on an undulating lower level, about thirty feet above the lake in the river bottoms, but the gravel terrace, which here lies on the St. Peter sandstone, is about a quarter of a mile wide, and from it there is a rapid undulating ascent to the uplands.

From Mendota to St. Paul the Trenton and St. Peter constitute an abrupt bluff, and there is no gravel terrace interposed between it and the river.



GLIMPSE OF MENDOTA. P.S FORKART HALL

1. GEN. SIBLEY'S STONE HOUSE.
2. STORE OF THE FUR COMPANY.
3. COURT HOUSE.
4. FARIBAULT'S HOUSE USED AS A HOTE.
5. POWDER HOUSE.
6. GEN. SIBLEY'S STABLES.
7. CATHOLIC CHAPEL

Gravel terraces of the Mississippi.

From the limits of St. Paul a gravel terrace skirts the west side of the Mississippi with persistence, as far as to Nininger; and after a brief interruption returns and prevails over the rocky outcrops toward the southeast as far as the Goodhue county line.

In the northeastern part of Inver Grove this terrace is about one hundred and twenty feet above the river. Further south it spreads over the open country, constituting the prairies of eastern Rosemount and southern Nininger, and thence southeasterly, its level being about nine hundred feet above the sea. Within this level, however, along the river is developed another, lower, gravel terrace which rises about eight hundred feet above the sea at Hastings. The upper prairie is covered by gravel that can be referred at first to the action of the Mississippi on the morainic accumulation in Inver Grove, and further south to the joint action of the Mississippi and the Rich valley channel, as already mentioned. At a slightly later date the Mississippi was deprived of the waters of the Rich valley channel, and at the same time was somewhat lowered, in its own bed, so that when finally shrunken to its present size it was bounded by an individual terrace distinct from that of its highest stage. Still, owing to the uncertain action and hight of pre-existing rock-bluffs through eastern Rosemount, there is a degree of uncertainty about the true classification of the various smaller benches and gravel plains that are to be seen in this part of the county. Several appear that are short. They consist essentially of gravel and sand, but a sandy loam covers them all. Toward Nininger begins to appear a fine, clay loam on the highest ground, covering particularly the region immediately south of Nininger.

The gravel plains of the interior towns. After having described the terraces of the main streams that cross the county, and of those that form its northern periphery, the whole of the gravel deposits of the county have, in general, been described. A few additional details, however, will be of importance to a thorough knowledge of these very interesting features of the county.

The channel that extends southeastwardly from Crystal lake is cut in the St. Peter sandstone, the overlying Trenton layers in some places giving it form along the margin of the upper prairie. These layers can be seen occasionally, but they are usually wholly concealed by the copious gravel of the upper prairie. Sometimes the edge of the gravel terrace is distinctly traceable as an independent line of bluff, separate from the strike of the Trenton. The upper prairie, in Lebanon, is about forty feet higher than the lower prairie.

The plains of Marshan, consist, so far as known, of gravel to a great depth, wells penetrating one hundred feet without striking rock. It seems that some great excavation has taken place here in pre-glacial times. The plain slopes from ten to fifteen feet gradually toward the south, with an increasing lightness of soil. It also becomes shrubby in the southern part with burr and black oaks. In the southern part of Marshan, before the rock again appears, causing an increase of hight of the general contour, the surface is slightly undulating, and is characterized as sandy oak openings. There is a narrow sandy valley extending from the S. E. ¼ of sec. 35, Hastings, southward through Marshan, passing through secs. 2, 11, 14, and widening out into sandy oak openings in secs. 22, 23 and 24, the surface of which seems to have been formed by currents or waves acting on light sand. This narrow valley, which is about a hundred feet below the general level of the plain, must have been due to the passage of a part of the waters of the Mississippi at a much later date than that which witnessed the flooding of the higher prairies of the town.

At Etter a small stream joins the Mississippi; it has bluffs of gravel an- sand eighty feet in hight, with no visible rock. Such bluffs bound the river thence to within about two miles of Hastings.

East of the "big slough" in Castle Rock, which is a part of the Farmington flat, and south of it, the terrace lines of the ancient drainage courses blend with the lines of the Trenton and St. Peter outcrops and in some instances the terrace has the full hight of the Trenton bluff. Although at present this slough has an outlet by the Vermilion, it is plain that when the waters were abundant on the county it had a broad outlet eastward through Hampton and probably reached the Cannon by way of Trout brook in Douglass. Through Hampton, however, this channel loses its directness, and its appearance of an old river shore. It is broken by innumerable tributary valleys, and broad swelling curves that return upon themselves both toward the north and toward the south.

Boulders. In a few places special notes were made of the distribution and size of boulders of granite and limestone. Of the latter the greatest number were seen always in conjunction with the gray drift. The gravel derived from the gray till is very largely made up of limestone from some formation that is not known in outcrop toward the northwest within the state, and which as a general distinguishing name has been alluded to as *Winnipeg limestone*, though it is probably from different formations extending from Lower Silurian to the' Devonian. Yet such limestone boulders also are found in the red till. They were noted at the following places: In the S. W. ¼ sec. 13, Eagan, are several fragments of this limestone, very fine grained and similar to the Devonian limestone at Le Roy, in Mower eounty. The drift at the same place is gravelly and reddish, apparently the same as that seen generally in this part of the county. Between this place and Mendota three other similar pieces were noted, one being in sec. 34, Mendota. In the northwest part of Inver Grove (secs. 6 and 7), are seen numerous pieces of the Treutou limestone among the morainic material. On the N. E. ¼ of sec. 19, Hamptou, amoug the boulders of the old drift lying below the loam of the country, which consist, seveuty-five to niuety per cent of them, of granite and syenite, are occasionally seeu pieces of Winnipeg limestone. The others are pieces of dike-rock, quartzyte and micaceous gneiss. At one and a half miles southwest from Mendota the drift is red with an oeeasional piece of northern limestone, of which two pieces were seen that were rough and about three feet across, resembling the upper surface of the Niagara seen at point Seul Choix, on the north shore of lake Michigan. On the N. W. ¼ of sec. 25, Burnsville, is a large northern limestone boulder, not far north of Walter Connolly's residence, lying on the terrace, or on one of the gentle elevations of till that rise above the terrace. Much of this is coarsely vesicular, and somewhat carious, yet in the gross very firm, with firm and compact projecting corners. This limestone mass is about nine feet across in one direction and five feet from side to side, rising about twenty inches above the ground. Near this are several others which weather nearly white, very firm and compact. These are probably all from the same mass, as much of the larger mass is like the smaller white ones. The interior is light drab and blotched, varying to light buff.

Other boulders were noted as follows: An immense, solitary granite boulder lies in the low land, near the level of the lower prairie on the N. W. ¼ sec. 26, Lakeville. By the side of the road, S. W. ¼ of sec. 35, Eureka, is a granite boulder rising four feet above the ground, nearly circular, and having a diameter of about twelve feet. It is coarsely crystalline, some of the orthoclase crystals being an inch and three-quarters across, though generally not more than half an inch, and of a light pink color. A large granite boulder lies in the low land on Peter Thompson's farm, N. W. ¼ of sec. 28, Eureka. Others, smaller, are thickly strewn over the same field. On sec. 17, Castle Rock, near the school house, is one of granite about ten feet long. On the N. E. ¼ of sec. 3, Randolph, on the St. Peter slope, is a granite boulder which stands about ten feet high, and is twelve feet in diameter. On the N. W. ¼ of sec 2, Randolph, likewise on a knoll which is produced mainly by the St. Peter, is a collection of large boulders, in the highway between secs. 2 and 35. Among these are numerous pieces of siliceous, non-magnetic iron ore one of which on analysis was found to contain 35.71 per cent of metallic iron, and 47.75 per cent of insoluble matter. Of the boulders generally distributed through the red till in the northern part of the county, were seen specimens of granite, red and gray, melaphyr trap, brick-red felsitic granite, fine, dark hornblende schist, gabbro (near the old site of Fort Snelling, on the south side of the Minnesota near Mendota, a specimen was seen five feet long by three and a half feet across), gray quartzyte of the Animikie rocks, brown felsyte, red porphyry. Pieces of rock resembling catlinite, with white and yellowish spots, easily crumbled, somewhat like shale, were seen on the Trenton mounds at the quarry of —— Shantz, just south of the Cannon river, in Stanton, Goodhue county.

A piece of *native copper* was found near Rosemount station, and two others in sec. 8, Hampton. A piece of *hæmatite* weighing thirteen pounds is said to have been found in the drift in the southern part of Vermilion township.

Loam. The distribution and origin of the rich yellow clayey loam, generally pebbly but nearly or quite free from boulders, are of great interest, since they can not yet be satisfactorily explained. It seems that the deposition of this loam must have antedated that condition of drift-transport which produced the gravel and sand of the plains, and the terraces of the rivers, since it is found on the old drift areas which rise from fifty to one hundred and fifty feet above those gravel plains. This clay-loam should be distinguished from that which forms the soil generally throughout the gravel-plains. This is a sticky, yellowish, clayey loam; that is sandy, and blackened to a greater depth by decayed and charred vegetation. It covers the high lands in northern and southeastern Lakeville, southern Greenvale, and the ridge of Trenton that runs through Castle Rock and Hampton, as well as the high land in Douglass. It is seen in the northeast part of Nininger and the northern part of Empire. It seems to grade into a finer pebbleless loam in some situations; and when it is covered by the alluvium of the rivers, or by gravel and sand, its equivalent then seems to be useful for brick-making. A deposit of this kind seems to exist in the Minnesota valley at Hamilton, and in the valley at Hungry point, sec. 33, Ravenna, where it is covered by a few feet of sand. There is here, at Hungry point, a sharply defined narrow valley eroded by the present creek which runs to Etter, the bluffs being fifty to seventy feet high, the rock-bluffs being about a mile separate. This clay is yellowish, or orange-yellow, and below a depth of a variable number of feet it becomes bluish, especially if it is so situated as to be continually wet. This seems to have been a sheltered bay, or coulée, in which the northern waters circled round and deposited the finest suspended materials. It is therefore of preglacial or interglacial age.

Kames. The only place known in Dakota county where the gravel and sand washed from the ice is so disposed as to constitute kames, is in the old Rich valley channel, in sec. 1, Eagan. Here are two gravel ridges that can be traced, one or the other, about a mile and a half, running south, and thence southeastwardly, about parallel, with one or two divergent branches near the southern extremity. It is noticeable first in the N. E. ¼ of sec. 2, Eagan, where the Dodd road runs on it for about half a mile. It is in the angle between the two branches of the great transverse valley. More or less water lies in the low land on each side. Toward the north it rises and spreads out into a rolling, gravelly, wooded expanse in which no kame-like form remains, but which is of the same nature as very much of the morainic region in Dakota county. It is probable that other kame-like ridges exist in this part of the county. They would be likely to occur in some of the valleys running southeastward; and they indicate the former presence of drift-laden ice undergoing dissolution, and the gathering action of the streams which carried away the water.

Wells in Dakota county.

Eagan. Patrick Fee; S. E. ¼ of sec. 12: well, 74 feet deep, all gravel and sand. A quarter of a mile north from this well, near the middle of the east half of sec. 12, is a lakelet in a hollow of the modified drift, 75 feet below the general level.

George Ange; S. W. ¼ sec. 4: well, 6 feet deep, all in a yellowish loam which lies on a bluish pebbly clay. This is situated on the undulating lower flat that runs along the river bluff.

J. Slater; S. W. ¼ of sec. 19: well, 47 feet; solid stony blue clay, 25 feet; sand, 8 feet; gravel, 14 feet; driven in material unknown, 16 feet. This is situated on the slope of the blue clay hills. Another well of Mr. Slater's, situated on the flat at the foot of the clay hill, is 26 feet deep, viz.: loam and clay, 8 feet; fine sand, 18 feet.

George Scott; N. W. ¼ of sec. 19: well, 26 feet; loam, 18 feet; sand 18 feet.

Patrick Qualy; E. ½ of S. W. ¼ of sec. 19: three wells, 110-150 feet deep; nearly all sand, but got good water. These are on the high hill east of the river road.

At Westcott station wells are 50 feet deep, being all in gravel and sand.

Mr. —— Tripp; S. ½ of the N. W. ¼ of sec. 27: well, 18 feet; good water in gravel.

Inver Grove. Mr. —— Rolfing; N. W. ¼ of sec. 9: three wells, 75 feet, 100 feet and 152 feet deep, without obtaining water, passing through only gravel and sand. The country here is very rough, and about a thousand feet above the sea.

Patrick Borden; S. W. ¼ of sec. 14: well 112 feet deep; soil, 2 feet; till, 8 feet; sand and gravel, 102 feet, to limerock; no water.

Reuben Freeman; S. W. ¼ of sec. 14: well, 120 feet deep; soil, 2 feet; till 10 feet; thence gravel and sand, 108 feet, to water. The wells of Messrs. Borden and Freeman are in a tract of the moraine similar to that of Mr. Rolfing, and about 125 feet above the Mississippi, a half mile distant. This morainic belt rises fully two hundred feet above the river within the distance of a mile from the river.

John Jagoe; N. W. ¼ of sec. 28: well, 140 feet deep; wholly in gravel, with good water. The general surface is rough.

E. J. Dresser; near the centre of sec. 34: well, 196 feet deep; stony and clayey soil and ordinary till, 5 feet; gravel and sand (except a layer of clay two feet thick, 30 to 35 feet below the surface), 191 feet. Water in quicksand at the bottom, probably nearly on the same level as the Mississippi river. This is on the smooth margin of the moraine.

J. Whittemore; S. W. ¼ sec. 33: well, 50 feet deep; all gravel and sand; excellent water. Wells between this place and Westcott vary from 50 to 100 feet in depth, being all the way in gravel and sand.

Burnsville. James Newman; S. E. ¼ of sec. 13: well, 136 feet deep; all fine sand. This is in the high moraine nearly a thousand feet above the sea.

Michael Coffey; S. E. ¼ sec. 24: well, 24 feet; loam, 4 feet; reddish sand and gravel, 18 feet; hardpan, 2 feet.

Ed. McDonald; S. W. ¼ of sec. 32: well in blue clay; curbed with pine; has foul water. The surface generally is of red drift.

Lebanon. Mary Scott; sec. 27: well 34 feet deep; all sand. This is on the lower prairie. Wells in this vicinity are said to be supplied with water on a level with the surface of Crystal lake.

Mr. —— McQuillan; S. E. ¼ of sec. 29: well, 45 feet; in blue clay; but this is in a country of red drift.

In the southern part of sec. 35, near the top of the prairie terrace, a well was sunk some years ago which found water in gravel at 75 feet, after penetrating what is described as blue clay. The water rose suddenly to about the level of the water-bearing gravel of the "lower prairie." This well was curbed with pine and became foul. After some years it was filled up again.

Rosemount. At Rosemount village wells are generally from 80 to 100 feet deep; and the same is true over the flat country north, east and south from Rosemount. They first pass through a few feet of yellowish clayey loam, or stony clay (till?), and then enter sand and gravel, which continues till water is reached.

Thomas Leonard; at the west side of sec. 36: well 80 feet deep; soil, 2 feet; yellowish clay, 3 feet; sand and gravel, 75 feet, to water. Other wells in this flat expanse of modified drift, known as "Rosemount prairie," are 50 to 80 feet deep, being all in gravel and sand.

Lakeville. Michael Mahoney; sec. 6, bordering on Crystal lake: well, 86 feet deep; black loam, 1 to 2 feet; blue clay, pebbly, and with small pieces of coal, 80 feet; stones and gravel, with water, 4 feet.

William Mahoney; sec. 6, on the shore of Crystal lake: well, 20 feet; all in blue clay, except at the bottom where water was obtained in gravel.

Henry Green; N. E. ¼ sec. 6: on the summit of a big hill, all the way in blue clay; water seeps.

John Murphy; E. ½ of S. E. ¼ of sec. 9: well 145 feet deep; loam and sand, 13 feet; blue clay, 132 feet; good water. At the depth of 60 feet he obtained two pieces of wood. In the debris thrown out is unmistakable Cretaceous iron-stone and fossil wood. The blue clay contained but few stones — only gravel-stones. At this place the surface is a high and undulating prairie, a thousand feet above the sea, and is covered with a fine loam and sand, the loam being reddish.

At Fairfield water is found in wells at the depth of about 20 feet, gravel and sand beginning below three feet, the soil and loam being about four feet thick.

Empire. Wells at Farmington are about 20 feet deep, in gravel, with a black sandy soil covering.

Vermilion. N. E. ¼ sec. 8: well, 92 feet; wholly in gravel, except the loam and soil.

Judge T. O'Leary, of Hastings, stated in correspondence, in 1878, that in a well sunk in this township pieces of wood and of a Cretaceous *Belemnites,* were obtained at the depth of 110 feet. These were sent the writer for examination, and were returned as requested. Further inquiries, for particulars, requested at that time, and again recently, fail to elicit any response.

Marshan. Dennis Macnamara; sec. 1: well 140 feet deep; blue clay, 100 feet; limerock, 40 feet;

no water. This well is on the southeastern slope of the well-known "mound." The blue clay had small stones; another well, 20 rods distant, obtained water at the depth of 40 feet.

Mr. —— Murtagh, about 80 rods south of the little mound, struck blue clay in a well at 60 feet, getting good water. The great plain south and southeast of these mounds is of gravel and sand, wells are about 100 feet deep and get good water.

Eureka. N. E. ¼ sec. 21: In a well, at the depth of about 18 feet, a log was found resembling tamarack. This well is situated on the gravel plain south from Fairfield.

Ole E. Forstrum; sec. 22: well, 38 feet; soil, 2 feet; stratified yellow clay, free from gravel, 6 feet; stratified blue clay, 12 feet; coarse gravel, with pebbles up to six inches in diameter, 8 feet; white sandstone (St. Peter), solid and hard, but cut by a dull axe, 10 feet, supplying water scantily. Another well on this farm, about fifty rods southeast from the last, and on lower land, was 16 feet deep, being stratified clay, 12 feet; gravel, 1 foot; and sandstone 3 feet.

Castle Rock. F. Schellenbarger; S. E. ¼ of sec. 29: well, at the depth of 25 feet, found sticks and other woody remains, affording a water with bad odors. This is on high land.

Henry Croft; S. E. cor. sec. 16: well, 44 feet; clay mixed with gravel, 15 feet; white sandrock, 30 feet; water is hard.

Henry Ehler; N. E. cor. sec. 21: well, 45 feet; gravel and sand, 5 feet; white sand rock, 40 feet, water soft.

Hampton. Seth Cain; S. W. ¼ sec. 8: well, 87 feet; soil, 2 feet; yellow till (?) quite hard, partly picked, 20 feet; sand, 12 feet; sandstone, 28 feet; hard "flinty" rock, 25 feet.

B. K. Ferris; N. E. ¼ sec. 9: well, 90 feet; soil and sand and yellow clay, with pebbles and stones, 20 feet; gravelly and stony blue clay, 30 feet; limestone, 25 feet; other stone said to be "very hard," 4 or 5 feet; good water at 80 feet. Another well situated a few rods southeast from this found water at 27 feet, passing through the yellowish clay into blue clay.

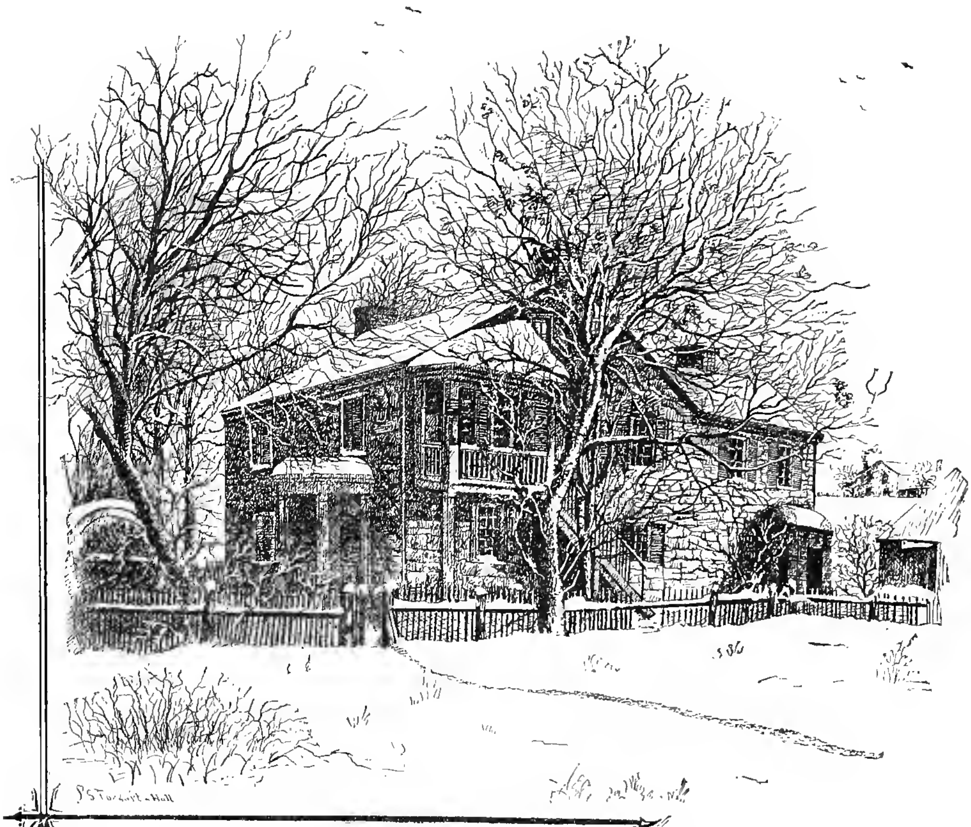
Greenvale. E. H. Wood; N. W. ¼ sec. 1: well, 34 feet deep; stratified gravel, sand, and clay, in layers varying from six inches to two feet in thickness, dipping 30° to 45° toward the west, 18 feet; dark bluish, very hard clay, probably till, picked, 10 feet; gravel, 2 feet; yielding water and containing a half dozen or more fragments of wood, from a few inches to one foot in length, thought to be red cedar, sharply splintered, not at all changed to lignite; underlain by the same dark, hard clay, probably till, as was above, dug into two feet and extending deeper.

John B. Simon; N. ½ of sec. 20: well, 40 feet deep; sand, soil and loam, 3 feet; quicksand, 16 feet; yellow clay, 5 feet; blue clay, 16 feet.

Jacob Simon; middle of sec. 20: well 40 feet deep; pebbly, yellowish-gray clay, 30 feet; blue clay, 10 feet. This well afforded Cretaceous debris.

Material resources.

Building stone. The quarries of the county have been enumerated in describing the formations in which they occur. The Trenton, wherever quarried, furnishes a very useful stone for the convenience of farmers in the central parts of the county. It is easily obtained, breaks out in blocks about four inches in thickness, and is cheaply wrought in shapes for foundations and all common walls. It has been used in the construction of several farm houses in the county, notably that of Mr. D. F. Aikin, a mile northwest of Farmington, and that of Thomas Hyland, on sec. 1, Lakeville. It might be burned for quicklime, of which the Lower Trenton beds will make a good quality. The stone being more nearly a pure limestone than any others found in the state, the lime that would result would be free from the objections which are made against limes that consist largely of magnesia. The walls would not be so apt to be fouled by the dripping of magnesian salts over the exterior.



Stone house of General H.H. Sibley; Mendota. Built in 1830

FIG. 11.

The magnesian limestones are not much wrought in Dakota county. The quarries that are found near Nininger supply a good stone, equal to any in the state, and their product is employed in St. Paul in some of the principal buildings. The stone is similar to the Frontenac stone of Goodhue county. The St. Peter sandstone furnishes sand for mortar in several places, but generally the drift gravel is used instead. The quarry in the St. Peter near Fort Snelling has been used not only for bridge-piers, but a small house owned by Treffle Auge, three miles from Mendota, near the Minnesota, was also built wholly of this stone. The first hotel at Mendota, built in 1838, by John B.

Faribault, is of sandstone, probably from this quarry.* There is an old brick-yard about a mile northwest from Farmington, which produced red brick.

This county, as already stated, embraces a great diversity of soil, surface, topography, and general agricultural adaptability. It has abundance of native forest, and extensive and fertile prairies. Its natural farm products are varied and remunerative. These features, combined with the water-power afforded by the small streams, and the commerce that goes and comes over the large ones, make Dakota county one of the most fortunate and one of the most prospectively wealthy counties of the state.

Artificial mounds. A great many artificial mounds are found on the east side of the Minnesota in Eagan township. They are on the great river-terrace which has been described, and near the western margin of the same. They are abundant on sec. 19, Eagan, on the farms of Mr. George Scott and Mr. Thornton. By long cultivation they have been flattened out. They are of all sizes, from ten feet to forty feet across, rising from two to five feet above the surrounding surface. They differ from the surrounding soil in being pebbly and sandy, and drying quicker after showers. When thus dry they are contrasted with the black color of the rest of the field. Twenty or thirty are visible on the farms of Messrs. Scott and Thornton. They are very uniform in outward appearance; occasionally they show a stone six inches in diameter, the soil generally being stoneless. They show nothing artificial, outwardly, and suggest an artifical origin only by their existence, and their resemblance to other mounds known to be artificial. They are uniform in slope, sub-circular, and are only on the highest parts of the terrace-flat, the general surface descending from them slightly east and west. They are regarded by the residents as "Indian mounds," but, according to Mr. James Slater, no Indian relics, such as arrow-points or pipes or hammers, were ever found in them, nor in the surrounding country. They extend along the terrace for a distance estimated as at least two miles.

This tract is well known as Black Dog, by the residents in this part of the county, and is probably the place at which major Long made a short stop in 1823, and which professor Keating made mention of under the name Oanoska.† The Indian village which he mentions, about six miles further up, as *Tetanketane*, must have been not far from Hamilton. Of these mounds professor Keating makes the following note: "On the right bank major Long observed numerous ancient tumuli or artificial mounds, some of which are of large size. They occupy a considerable extent of the prairie upon which they are situated. In one part they formed a line of about half a mile in a direction parallel with the river, from which they were distant about three hundred yards. The mounds were erected at a distance of from twelve to fifteen yards asunder, and when observed from one end of the line, presented the appearance of a ridge or parapet." The residence of these Indians in this region, and the fact that it is named Black Dog from an Indian dignitary of that name, can have no relation, therefore, to the occurrence and object of these mounds.

The road which passes south from Hamilton, on the boggy beach formed by the Shakopee, runs near a number of similar artificial mounds. Four are visible from the road on the west side, and three on the east side, within six or eight rods. These are from two to three feet high. In the village of Hamilton are several others, though smaller; and still more on the west side of Credit river between Hamilton and the Minnesota river.

In the east side of sec. 23, Greenvale, are several mounds of the same kind. They are situated so as to surround a marsh. There are several others on the S. W. ¼ of sec. 24. Six more were noticed on the S. E. ¼ of sec. 18. These are on the north side of the creek, near the highway.

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* Respecting this hotel the following note has been received from Gen. Sibley:

ST. PAUL, MINN., March 29, 1886.

Prof. N. H. Winchell, Minneapolis, Minn.,

DEAR SIR: Your favor of twenty-fifth inst. received this morning. The hotel referred to was built by John B. Faribault, father of Alexander, in 1838. The front is of sandstone, from the small island a short distance above Mendota. Whether the other sides of the building were of the same material, or of limestone, I do not remember. My impression is, however, that the front alone is of sandstone. Truly yours, H. H. SIBLEY.

P. S.—You are probably aware of the fact that my own house, built of limestone, is the oldest private residence in the state, commenced in 1835, and completed in 1836. That and the hotel still stand, and bid fair to so remain for many years to come. H. H. S.

† Narrative of an expedition to the sources of the St. Peter's river, etc., vol. i, p. 339.

In sec. 35, Eureka, and sec. 2, in Greenvale, on either side of the town-line road, are seen about a dozen artificial mounds. These are about two and a half feet high, and overlook what may have been a lake, but now is a marsh. Near the south line of sec. 34, Eureka, are six other mounds, from one to two feet in hight. These are on low, moist land, while swells thirty or forty feet high rise in the vicinity.

Two mounds, rising two to four feet, are in the yard of Thomas Butler, north side of Crystal lake, N. W. ¼ of sec. 32, Burnsville. Four or five more, of about the same size, are near the centre of sec. 31, on the north bank of the lake, about fifty feet above the water.

According to Mr. Lewis Judd, there are seven mounds on Mrs. Monghan's land, N. W. ¼, S. E. ¼, sec. 25, Burnsville, overlooking the east end of lake Early. These are on a narrow strip of land between Early and Middle lakes, rather close together. He excavated one, and discovered what appeared to be four layers of ashes, and some indications of rotting bones, but nothing that could certainly be identified as such.

CHAPTER IV.

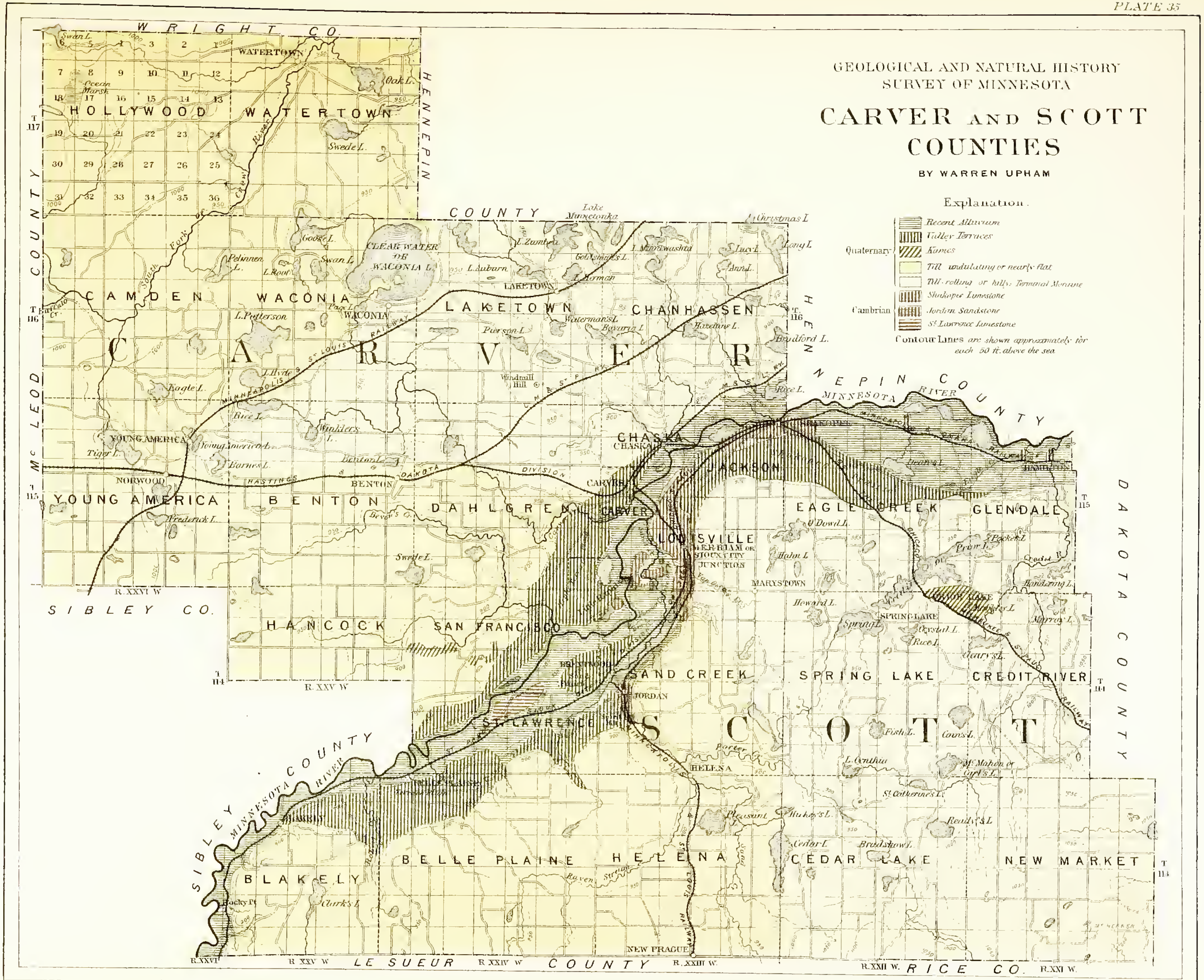
THE GEOLOGY OF CARVER AND SCOTT COUNTIES.

By WARREN UPHAM.

Situation and area. Carver and Scott counties (plate 35) adjoin each other, the former being on the northwest and the latter on the southeast side of the Minnesota river. Chaska and Shakopee, their respective county seats, are about twenty-five miles southwest from Minneapolis and Saint Paul. Other large towns and villages in Carver county, besides Chaska, are Carver, Benton and Norwood, on the Hastings & Dakota division of the Chicago, Milwaukee & Saint Paul railway; Laketown, Waconia and Young America, on the western line of the Minneapolis & Saint Louis railway; and Watertown, on the South fork of the Crow river, in the northern edge of the county. Important towns and villages in Scott county are Hamilton, Shakopee, Jordan and Belle Plaine, on the Saint Paul & Sioux City division of the Chicago, Saint Paul, Minneapolis & Omaha railway; Prior Lake, on the Hastings & Dakota railroad; New Prague, lying half in this county and half in Le Sueur county, on the eastern and main line of the Minneapolis & Saint Louis railway; and Marystown, Spring Lake and New Market, between the two roads last named.

The greatest length of Carver county from east to west is 24 miles, and its extent from north to south lacks only about a quarter of a mile of this distance. It includes nine entire townships of the governmental surveys, and fractional parts of four others. These form thirteen organized townships, eight of which are bounded wholly by the township lines of the original surveys and are each six miles square. The area of Carver county is 376.50 square miles, or 240,959.58 acres, of which 14,307.30 acres are covered by water.

The greatest length of Scott county from east to west is along its south boundary, which is a straight line 31 miles long. The greatest width of this county from north to south is 18½ miles. It includes five entire townships of



Julius Bien & Co. lith.

the United States survey, and fractional parts of ten others, which together form thirteen organized townships. The area of Scott county is 358.60 square miles, or 229,501.80 acres, of which 10,157.58 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The northwest part of Carver county including Hollywood, Watertown except its southern edge, Camden except its east edge, and the northwestern third of Young America, amounting to about 110 square miles, is drained by the South fork of the Crow river, which flows through this part of the county in an easterly and northeasterly course. Its most considerable tributaries in this county are, from its south or right side, Buffalo creek, in section 18, Camden, and the outlet of Tiger lake in the northeast quarter of section 21, of this township; and, from the west or left side, the outlet of Swan lake, which unites with this river in the north part of section 4, Watertown.

Minnetonka lake extends into this county at the north end of the line between Laketown and Chanhassen, and receives the drainage of about 15 square miles in the northern part of these townships.

The remainder of Carver county, about 250 square miles, belongs to the basin of the Minnesota river. The largest tributaries of this river from Carver county are Beven's creek, which has its source in Washington lake, Sibley county, thence flowing easterly eighteen miles to its mouth in section 11, San Francisco, after receiving a tributary nine miles long from the southwest at the east line of section 4, of this township; and Carver creek, whose sources are numerous lakes in Waconia, ten to fifteen miles northwest from its mouth, which is at Carver. Below these affluents three smaller creeks, each about six miles long, join the Minnesota river at Chaska, and at one and four miles further east.

Lake Waconia, or Clear Water lake, the largest body of water in Carver county, is about two and a half miles in diameter, lying principally in the northeast part of Waconia. Other lakes that deserve mention in this county are Goose and Patterson lakes, in the west part of this township, each about one and a half miles long; Swan and Page lakes and lake Hyd, each about a half mile long, in the same township; Swede lake, more than a mile long from east to west and a half mile wide, near the centre of Watertown, and Oak lake, about equal to the last in size, lying mostly in section 11 of this township; Swan lake, about a mile long, at the northwest corner of Hollywood and of this county; Pelinnea lake, mostly in section 12, and Eagle lake in section 34, of Camden, each about a mile long from north to south; Tiger lake, one and a half miles long from northwest to southeast, and averaging a half mile wide, mostly in section 9, Young America, and Young America, Barnes, and Frederick lakes, each about three-fourths of a mile long, in the east part of this township; Rice lake, one and a half miles long from east to west, at the north side of sections 5 and 6, Benton, and Winkler's, Benton, and Swede lakes, in this township, with others, varying from a quarter of a mile to one mile in length; a lake half a mile in diameter, in section 7, Hancock; a lake one mile long from north to south and from a quarter to a half of a mile wide, on the bottomland of the Minnesota valley in the northeast corner of San Francisco; another lake, of smaller size, on the bottomland between Carver and Chaska; and Rice lake, also on the Minnesota bottom, extending about a mile in the southeast corner of Chanhassen and reaching more than a mile farther east in Hennepin county; Bradford lake, about a mile long, also crossed by the east line of Chanhassen, a little more than a mile north of Rice lake; Long lake, one and a half miles long from northwest to southeast, but narrow, in the northeast corner of this township; Lucy and Ann lakes, of small size, one and a half miles farther west; Minnewashta lake, two miles long from north to south and averaging a half mile in width, lying mostly in sections 5 and 8, and Hazeltine lake, a mile long from northwest to southeast, in sections 21 and 22, Chanhassen; Bavaria lake and Goldsmith's lake, each about a mile long from northwest to southeast, crossed by the east line of Laketown; and lakes Zumbra, Herman and Auburn, in the northeast quarter of Laketown, an unnamed lake in section 5, and Waterman's, Pierson, and Reitz lakes, in the south half of this township, the last seven named being from three-fourths of a mile to one and a half miles long.

Nearly all of Scott county lies within the basin of the Minnesota river. The only exception is an area of about twenty square miles, forming the east part of New Market, at the southeast corner of the county, which is drained by the head-stream of the Vermilion river, and by a branch of Chub creek, a tributary of the Cannon river. The most noteworthy tributaries of the Minnesota river in Scott county are Robert creek, about five miles long, in the east part of Blakely; Sand creek, in the township of Sand Creek, about twenty miles long, having its farthest sources in the northeast part of Le Sueur county, and receiving two tributaries in central Scott county, a few miles above Jordan, namely, Porter creek from the east, and Raven stream from the west, each some ten miles long; and Credit river, which joins the Minnesota at Hamilton, having its sources twelve to fifteen miles distant on the south, in the northwest part of New Market.

The three largest lakes of Scott county are Credit or Prior lake, four and a half miles long from northeast to southwest and mostly from a quarter to a half of a mile wide, crossed at a narrow place by the Hastings & Dakota railroad; Spring lake, a short distance farther southwest, occupying a continuation of the same irregular and interrupted line of depression with the preceding, one and a half miles long and two-thirds of a mile wide; and Cedar lake, two miles long from north to south, and from a third of a mile to one mile wide, crossed by the line between Cedar Lake and Helena townships. Among the other lakes of this county the following seem worthy of note: Dean's lake, a mile long and a quarter of a mile wide, in sections 10 and 15, Eagle Creek; another lake, of about the same area, in sections 6 and 7, Glendale; and a third, of somewhat larger size, about a mile west of Shakopee, these being on the bottomland of the Minnesota valley; O'Dowd and Hahn lakes, each about a mile long, in the east part of Louisville, the former being crossed by its east line; a lake one mile long from northeast to southwest, in sections 11 and 14, Sand Creek; Sutton lake, nearly two miles long from northwest to southeast and from one-sixth to one third of a mile wide, lying mostly in section 25, Sand Creek, and crossed by the east line of this township; Hickey's lake, a half mile long, lying half a mile north of Cedar lake; Pleasant lake, about a mile in diameter, in sections 10 and 11, Helena; Clark's lake, about a mile long from north to south and a half mile wide, near the centre of Blakely; Bradshaw lake and Ready's lake, each about a mile long from east to west in Cedar Lake township; lake Cynthia, St. Catherine's lake, and McMahon or Carl's lake, each about a mile in extent, at the north line of Cedar Lake, the latter lying mainly in section 36, Spring Lake; Fish, Howard, Rice and Crystal lakes, in Spring Lake township, varying from one-third to two-thirds of a mile in length; Cain's lake and Cleary's lake, each a mile long from east to west, crossed by the line between Spring Lake and Credit River townships; Murray's lake, a half mile in diameter, in sections 3 and

4, Credit River; and Handering lake, a mile long from northeast to southwest, in the southeast corner of Glendale. The lakes of these counties lie in depressions of the drift, and vary in depth from five to twenty-five, and occasionally, perhaps forty feet. Some of these lakes have no streams flowing either into or away from them.

Many of the smaller and shallower hollows upon the drift-sheet are occupied by marshes or sloughs, destitute of timber and bearing a heavy growth of wild grass which is mostly gathered for hay. Excepting these marshes, the lakes, and the steeply sloping bluffs which border the valleys that have been cut by creeks and rivers, all the lands of these counties may be profitably cultivated. By its undulating and in some portions prominently rolling contour the surplus water of rains and of snow-melting is quickly carried into the numerous channels of drainage, giving opportunity for early sowing. The porous nature of the soil, which absorbs much moisture and gradually yields it up to vegetation, the usually plentiful supply of rains through all the spring, summer and fall, and the excellent natural drainage afforded by the gentle slopes of the land, combine to insure a bountiful harvest to the diligent farmer every year, without the interruption of occasional failures because of either droughts or excessive rains.

Topography.

The terminal moraine. About a third of Carver county, in its northeastern and central portion, is occupied by the hills and swells of the terminal moraine, which was accumulated in the last glacial epoch, being pushed outward by a lobe of the ice-sheet whose currents in Carver and Scott counties moved from the west to the east, northeast, and southeast. This area includes Chanhassen, Laketown, the northwest part of Chaska, northern Dahlgren and Benton, to the line of the Hastings & Dakota railroad, the southeastern third of Waconia, and the northeast part of Young America. In journeying southwest from Minneapolis to Carver county, this prominently rolling or hilly belt of morainic drift is entered at the southwest edge of that city, which has hills 150 to 175 feet above the Mississippi river, or 950 to 975 feet above the sea. Through the fifteen miles southwestward by Minnetonka City and Excelsior, south of lake Minnetonka, hills and massive swells of till or boulder-clay abound, rising from 40 to 75 and rarely 100 feet or more above the depressions and the lake, which is 928 feet above the sea. These hills seldom present very rough outlines, broken by small knolls, hillocks and ridges, such as mark the moraine in many portions of the state; instead, they commonly have rather smooth slopes, in some places steep, elsewhere prolonged, and so joined and grouped as to exhibit much variety in their location and form. About Eden Prairie, and in northeastern Carver county, this hilliness continues in a less degree, occupying all of Chanhassen and Laketown, and reaching its adjacent townships. From the southwest part of section 12, Chanhassen, the view to the east and southeast is extensive, reaching over lower, moderately undulating land, and across the Minnesota valley, to the continuation of these morainic hills in eastern Scott county and northwestern Dakota county, fifteen miles distant. This part of Chanhassen is moderately undulating or rolling till, in swells 10 to 30 feet high. Through this township and westward in Laketown the land is everywhere excellent for farming, both as to its rich soil and the slopes of its surface which is rolling and hilly till, rising frequently 30 to 50 feet above the valleys, but having no very prominent elevations.

Waconia or Clear Water lake, the largest of this county, is a beautiful sheet of water, bordered by bluffs 20 to 40 feet high for half its circuit, alternating with low or gently sloping banks. By undermining the hilly portions of its shore, the lake is filling up hollows in its bottom, and its area is being slightly increased. Waconia village is finely located at the south side of this lake, on a rounded swell 30 to 60 feet above it.

Southeast from Waconia to Carver the land lies in massive swells, 30 to 50 feet high, often nearly level-topped. Windmill hill, in the east part of section 33, Laketown, is by barometer 120 feet above Waconia lake. This is not above other hills at the west, north, and northeast, but is slightly higher than the highest portions of the region southeast, south, and southwest, which has its elevations 40 to 60 feet above the hollows. A swamp 80 feet below this hill occurs within one-fourth of a mile south. The north half of Dahlgren and Benton, and the distance of nine miles from Norwood to Waconia, are all massively undulating or swelling, with crests 20 to 30 feet above the depressions. All these areas are till, or the unmodified deposit of the ice-sheet, consisting mostly of clay, but also including sand, gravel, and occasional boulders, the whole being mingled indiscriminately together. Farther to the northwest, west, and south, this county, except in the Minnesota valley, is almost everywhere composed of the same material, but it is there spread with a generally smooth and only slightly undulating surface.

The Minnesota river cuts across the morainic area between Carver and Hennepin counties on the north, and Scott and Dakota counties on the south. The river-bluffs here are mainly from 200 to 225 feet high, the river at its stage of low water being 690 feet above the sea, and the bluffs being therefore about 900 feet. The highest points of the morainic drift-deposits in the vicinity of the river are 25 to 50 feet higher. In Hennepin county the moraine extends along the north side of the Minnesota river to within about eight miles southwest of Fort Snelling. The river-bluff here is about 150 feet high, and a mile or two northward these morainic hills rise 100 feet higher, their tops being 950 feet approximately above the sea. This portion of the Minnesota valley is from one to two or three miles wide. In Carver, Chaska and Chanhassen, the bluff is about one mile distant from the river. From Carver and Chaska to Fort Snelling the bluffs along the north side of the river descend steeply from their top to the bottomland, which is mostly from 10 to 20 feet above the river. A conspicuous terrace of modified drift, about 125 feet high, extends along the west side of this valley above Chaska, through the south part of Carver county; and similar terraces occur on the southeast and south side of the river, in Scott county, at Belle Plaine, close west of Jordan, and for several miles southwest and east-southeast of Shakopee.

The west boundary of the moraine crosses the Minnesota valley into Scott county near Merriam or Sioux City Junction, in Louisville, half-way between Jordan and Shakopee. Below this the highest bluffs of the valley are from one and a half to three miles distant from the river. They are composed of till and form the margin of the rolling and hilly tract of morainic drift which thence reaches southward unbroken to the Iowa line. The east half of Scott county, as far westward as to the Minnesota valley at Merriam Junction, to the lakes in the east part of Sand Creek, and to Cedar lake, has a surface everywhere diversified by hills and swells, which are generally 30 to 40 feet high, often 50 to 60, and from 75 to 100 feet in a few places. From Merriam Junction east to Spring and Prior lakes, the contour is generally hilly, the elevations being 30 to 50 feet above the hollows, with no level intervening areas. East and southeast from these lakes to Credit river, the surface is in lower hills and irregular, rounded ridges of till, 25 to 40 feet high, with longer slopes and smoother outlines, and with frequent intervening marshes or lowlands a quarter to a half mile in width.

Prior lake is 907 feet above the sea, and the hills about it rise 40 to 60 feet. The village of Spring Lake is at the southwest end, and Prior Lake station on the Hastings & Dakota railroad is at its southeast side. At each end of this lake the land is plainly till, but wells at Prior Lake station show a very thick deposit of sand and gravel, extending from the surface to a depth of 210 feet, at which depth it was not passed through; and in the next one and a half miles east to Markley lake, modified drift, much of it water-worn gravel with pebbles up to six inches in diameter, forms hills 50 feet high. These hills, like the lakes, though irregular in their outlines, have a general trend to the east-northeast. Nearly all other portions of Scott county, except the Minnesota valley, are unmodified drift or till, and the hills of this deposit have no prevailing trend.

In the south part of Scott county the moraine has its most conspicuous development in sections 27, 28, 33 and 34, Cedar Lake, reaching also to the south and to the north and north-northeast. These hills, from 50 to 100 feet high, are numerous, not very steep in slopes, and nowhere specially rough in contour, or profusely strewn with boulders, which however are frequent. Intervening marshes and nearly level areas of modified drift, or slightly undulating tracts of till, occur here; and eastward they occupy the greater part of New Market. Scattered hills of till, of no uniformity in trend, outlines, or hight, which is from 40 to 75 feet, continue through this township (one of the most prominent being Mount Herber, at the southeast corner of section 27), and into the southwestern edge of Dakota county, where they gradually disappear in the first three or four miles. The contour is changed to a more smooth surface, nearly level upon areas one-half to one mile wide, with here and there swells or mounds of the easily disintegrated St. Peter sandstone, 30 to 40 feet higher.

Region west of the moraine. Two-thirds of Carver county, including Watertown, Hollywood, Camden, the northwest two-thirds of Waconia, Young America, except its northeast corner, the south half of the townships of Benton and Dahlgren, and the whole of Hancock and San Francisco, lie west of the morainic belt. Excepting the valley of the Minnesota river, these townships are till, slightly or moderately undulating, or in some portions nearly level. In Watertown and the northwest part of Waconia the surface rises and falls in gentle undulations or swells, whose crests are elevated 10 to 20 feet above the depressions. Hollywood is less undulating and in part almost level. Camden also is approximately level, the highest portions being only 5 to 10 feet above the numerous swamps or sloughs. The material nearly everywhere is till, in which the proportion of boulders and pebbles is small. Not much stratified drift is found, even along the south branch of the Crow river, which through Camden is bordered by land scarcely below the general hight of the region. Through Watertown the valley that has been cut by this river becomes a conspicuous feature of the topography, increasing from 25 to 50 feet in depth and varying from an eighth to a half of a mile in width.

The south part of this county, in northwestern San Francisco, southwestern Dahlgren, Hancock, the south part of Benton, and Young America, is slightly undulating till, which often extends nearly level for a half mile. Its highest portions are 10 to 20 feet above the hollows and lakes. The east part of this area, in Dahlgren and San Francisco, is the most rolling, but has no roughly knolly tracts. In the townships last named, shallow deposits of modified drift were seen near the south branch of Beven's creek, which, however, is a small stream with no well-marked valley. These beds, like the adjoining region of till, have a somewhat rolling surface.

In Scott county, west from Cedar lake and the lakes in the east part of Sand Creek township, to the Minnesota valley, the surface is everywhere moderately undulating or swelling, with prolonged slopes, the crests being from 10 to 30 feet above the depressions, which hold occasional lakes and sloughs. This area includes the greater part of Sand Creek, Helena, Belle Plaine and Blakely. At its northwest side, next to the Minnesota valley, it has an average elevation of 225 feet above the river, but about New Prague, at the south side of Helena, it is 50 to 75 feet higher.

The approximately level contour of this region is well shown by a comparison of the following hights, accurately determined by railroad surveys, which represent the average elevation of their vicinity above the sea: in Scott county, New Prague, 975 feet; in Carver county, Dahlgren, 994, and Norwood, 1,002; in Nicollet county, Oshawa, 980, and Nicollet, 978; and in McLeod county, Glencoe, 1,015, and Hutchinson, 1,033.

The Minnesota valley. The width of the Minnesota valley in Carver county, including only its side lying northwest of the river, varies from a half mile in the south part of San Francisco to three miles at the line between this township and Dahlgren. The top of the inclosing bluffs of till and the adjoining county are 225 to 250 feet above the river. The most interesting feature of the valley in this county is a terrace of modified drift about 125 feet above the river, which extends twelve miles from the east line of Sibley county, through San Francisco, Dahlgren and Carver, terminating at Chaska. Through a distance of three and a half miles, lying between Beven's and Carver creeks, in northeastern San Francisco and southeastern Dahlgren, the width of this terrace-plain is from one and a half to two and a half miles; but farther northeast and southwest its width varies from a fourth or a third of a mile to only a few hundred feet. Its material is horizontally stratified gravel, sand and clay, as is finely seen in sections 30 to 50 feet deep, exposed by the valleys of the creeks and at the brick-yards of Carver. This is a part of the flood-plain that was deposited in the valley at the close of the glacial period, and at that time it reached in a level expanse across the space where it has been since excavated by the river, to the similar remnants of this modified drift, which form terraces at Belle Plaine, Jordan and Shakopee.

The bottomlands of the Minnesota valley in Carver and Scott counties are from a half mile to one and a half miles wide. These lands, which would be called *intervals* in the eastern states, are mostly overflowed by the river in spring when the snow melts, and rarely by floods produced by great rains at other seasons of the year. One peculiarity sometimes exhibited by these alluvial areas, is a wavy surface, which was noted for a mile south from Carver in driving to the Little Rapids. It was also seen in section 1, Tyrone, in the northwest corner of Le Sueur county, for about a quarter of a mile north from the Henderson bridge; and again in Scott county, between the west part of Shakopee and the river. These undulations are from five to twenty rods apart, from three to six feet in hight, and from a hundred feet to an eighth of a mile or more in length, which is approximately parallel with the direction of the valley and the river, their hight above the river being from 10 to 20 feet, and within range of its highest floods. Their steepest slope is generally toward the river. Every portion of the bottomland has been at some time occupied by the constantly varying channel of the river; and these low, wave-like ridges, which were called *glacis terraces* by Dr. Edward Hitchcock, appear to be successive river-banks, recording some of these changes.

At the west side of Scott county, the till-bluffs of the river are distant from an eighth or a fourth of a mile to two and a half miles. This distance is least at the west side of Blakely, where the bluff is separated from the river only by bottomland through which the river flows in a winding course, alternately approaching the foot of the bluffs at each side. Conspicuous remnants of the old flood-plain of modified drift, which at one time filled this whole valley, are seen at Belle Plaine, at Spirit hill and at the "sand prairie" near Jordan. The nearly level area of modified drift upon which Belle Plaine is built, extends about three miles from this place both to the east and west, its whole length being six miles, from section 9, Blakely, to section 33, St. Lawrence. This tract is crossed by Robert creek about one mile west of Belle Plaine, its width there being one mile. West of this creek it is mainly wooded, but eastward it forms a flat prairie one and a half miles wide. Its hight above the river is about 135 feet. A depression 20 to 30 feet lower and a quarter of a mile wide, extends along its whole southeast side, dividing it from the upland of till whose bluffs rise steeply 80 to 100 feet above the plain. North of Belle Plaine the descent to the railroad is about 100 feet, by a bluff which is composed in its lower half of till, being stratified sand and fine gravel in its upper 40 or 50 feet, which is the thickness of modified drift found in the wells of Belle Plaine. Within a mile south of the town this is increased to 60 and 70 feet. Underneath is ordinary till, into which some of these wells go 50 to 75 feet. North of the east end of this plain the road at the east side of section 32, St. Lawrence, crosses a well-marked lower terrace of the same stratified gravel and sand, the descent to it being 10 or 15 feet by a moderately sloping escarpment.

Eastward the next remnant of the flood-plain is Spirit hill, so named by the Sioux who held councils or powwows here. This name, however, is applied only to the east half of this terrace of modified drift, which extends three miles, from the northeast corner of section 34, St. Lawrence, east-northeast to Jordan. It is intersected by a creek about a mile from its west end, where its width is a half mile. Thence to Jordan it is from a half mile to one mile wide. In hight it is about 130 feet above the Minnesota river, and 100 feet below the surface of the sheet of till whose border rises in steep bluffs at its south side and east of Sand creek. A wide hollow next to the foot of the bluff on the south is about 20 feet below this terrace-plain. Wells here go 60 to 80 feet in stratified gravel and sand, and below find either till or a stratified clay like that which forms the base of this terrace at its northeast end, and is there used by Charles Rodell for brick-making.

Another remnant of this valley drift is the plateau called the "sand prairie," which lies a mile north of Spirit hill. The hollow dividing them is occupied by a marshy tract and creek, and affords passage to the Saint Paul & Sioux City railroad. The "sand prairie" rises some 50 feet above this depression and 110 or 120 feet above the river, in slopes which differ from those commonly seen in bluffs, whether of modified drift or till, by having a less steep ascent and a rounded junction with the plain above instead of the usual abrupt edge. This "sand prairie," including its slopes, is about two miles long, extending east-northeast from the northeast quarter of section 23, through section 13, St. Lawrence, and the northwest quarter of section 18, Sand Creek, its width being about a half mile.

The railroad through St. Lawrence township is about 60 feet above the Minnesota river, and crosses an area of somewhat irregular surface, one and a half to two miles wide, extending from the modified drift of Belle Plaine and Spirit hill to the river. This tract has considerable marshes at its south side while its central and northern portions are drift, quite profusely sprinkled with granite boulders up to six or rarely ten feet in diameter. This is doubtless underlain at no great depth by the St. Lawrence limestone, which outcrops along a distance of some two miles between the railroad and the river, in sections 28 and 22, having its top about 45 feet above the river.

In the north part of Scott county the bluffs of till that bound the Minnesota valley are from one and a half to three miles distant from the river, the valley being broadest in its six miles occupying the north half of Eagle Creek township. Within these bluffs are an extensive terrace of modified drift, terraces of the Shakopee limestone underlain by Jordan sandstone, and the ordinary bottomland of the valley. Outcrops of the Jordan sandstone, in irregular mounds or plateaus and a terrace, 30 to 50 feet in hight above the river, occur four to six miles north of Jordan, reaching from the north edge of Sand Creek township to Merriam Junction in Louisville. The land in the mile northwest from Merriam Junction to the Minnesota river is rough with irregular low hillocks, which rise 25 to 50 feet above the river and are composed of this sandstone capped by Shakopee limestone, generally overspread by a few feet of drift in which limestone fragments abound. Beside the railroad a half mile north of the Junction the Shakopee limestone, about level in stratification, forms a terrace approximately 115 feet above the river. Limekilns at this place use stone quarried from the upper half of this terrace, which is about 40 feet above a second terrace made by the lower part of the same limestone formation. The upper terrace, an eighth to a quarter of a mile wide, is formed of the limestone, usually thickly covered by modified drift, through a distance of about a half mile, lying close east of the Saint Paul & Sioux City railroad. Northeastward this terrace, without noticeable change in hight or appearance, is composed wholly of modified drift, or stratified gravel and sand, this being the west end of the formation whose broadest part is called the "Shakopee prairie."

A level-topped outlier of the upper terrace of limestone, covering an area of an acre or more, occurs a quarter of a mile west of the lime-kilns. Its top is only a few feet below that of the terrace at the kilns, and is some 40 feet above the lower terrace of limestone on which it lies. The railroad for two miles thence northward runs on the east edge of the lower limestone terrace, which is about one-third of a mile wide, and has most of its surface thickly strewn with boulders of granite and crystalline schists. At its east side there is an ascent of 40 or 50 feet to the terrace of limestone and northward of modified drift; and on the west it has a descent of about 50 feet to the alluvial bottomland.

At its north end this terrace is succeeded by a plateau of modified drift, about a mile long from southwest to northeast and a third of a mile wide, which lies opposite to Chaska, rising steeply east of the railroad bridge to a nearly level top, 110 to 125 feet above the river. The hollow in which the Saint Paul & Sioux City railroad runs at its east side is some 50 feet lower, beyond which next eastward is the terrace of modified drift with its top on a level with this plateau. The top of both plateau and terrace are sand and gravel, nearly free from boulders, which, however, are very abundant on the south and southeast face of the plateau, as also on the limestone terrace below.

South of Shakopee and through several miles eastward a plain of modified drift, about 75 feet above the railroad station and 140 above the river, is a marked topographic feature of the Minnesota valley. The entire length of this gravel and sand terrace is ten miles, beginning a little north of the lime-kilns in Louisville, and extending northeastward with a width from a fourth to a half mile for the first three miles, to section 11, Jackson. Thence it reaches east seven miles, through this township and nearly to the east line of Eagle Creek, with a width varying from one to one and a half miles. All of this county was originally wooded, excepting much of the bottomland of the Minnesota valley and of its terraces, such as that of Belle Plaine and this close south of Shakopee, which latter has therefore received the name of "Shakopee prairie." Numerous wells on this terrace show the depth of stratified gravel, sand and clay to be from 40 to 50 feet, underlain at a hight about 90 feet above the river by the Shakopee limestone, the continuation of the same strata that form the terraces in Louisville. Through the corporate limits of Shakopee this limestone is exposed at many places, the top of the portion visible being 50 feet above the river. It is usually separated from the river by an area of bottomland from a few rods to a quarter of a mile wide.

For two miles west of Shakopee and through the ten miles east to Hamilton, the bottomland is from one to two and a half miles wide. In former times the river has often changed its course upon this low alluvial area; and portions of its deserted channels, and broader depressions which have not become filled with its sediments, remain as lakes. Three of these are each about a mile long, one being situated a mile west of Shakopee; another, Dean's lake, four miles east-southeast, at the northeast foot of the modified drift terrace, and one and a half miles from the river; and the third, two miles farther east, near the river, in sections 6 and 7, Glendale. From the south side of Shakopee prairie the bluffs of till which form the limit of the Minnesota valley rise 80 to 100 feet above it, or to a hight about 225 feet above the river.

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.
Summit, grade, in the east edge of Credit river, near the line between Dakota and Scott counties,	26.5	1080
Natural surface here,	26.5	1090
Summit, grade, $\frac{1}{3}$ mile east of Prior lake,	32.8	959
Natural surface here,	32.8	971
Prior Lake station,	33.1	947
Prior lake, surface of water (which is 25 feet deep),	33.7	907
Cut, grade, $\frac{1}{2}$ mile farther northwest,	34.2	937
Natural surface here,	34.2	963
Cut, grade, 3 miles northwest of Prior Lake station,	36.1	901
Natural surface here,	36.1	926
Shakopee, crossing the Saint Paul & Sioux City railroad,	41.5	753
Minnesota river, grade on bridge,	44.5	725
Minnesota river, low and high water; range 29 feet, (Depth of the river here at low water is 22 feet.)	44.5	690–719
Chaska,	45.4	726
Chaska, crossing the Minneapolis & Saint Louis railway,	45.5	728
Carver,	47.5	813
Grade on bridge over road, $\frac{1}{4}$ mile west of Carver,	47.75	816
Bottom of ravine, beside the road,	47.75	747
Dahlgren,	50.9	980
Divide, $\frac{1}{2}$ mile west of Dahlgren, grade,	51.4	981
Natural surface here,	51.4	987
Carver creek, grade on bridge,	52.3	928
Carver creek, water,	52.3	907
Benton,	55.6	945
Divide, $\frac{3}{4}$ mile west of Bonngard's crossing, grade,	60.0	989
Natural surface here,	60.0	998
Norwood,	62.9	988
Tiger lake, water,	65.0	977
Divide, $\frac{1}{2}$ mile east of the line between Carver and McLeod counties, grade,	66.5	1002
Natural surface here,	66.5	1008

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 Saint Paul.	Feet above the sea.
Hamilton,	17.7	720
Eagle creek, bridge,	19.7	714
Bloomington,	21.2	744
Shakopee,	26.8	747
Summit, grade,	28.8	760
Summit, grade,	32.6	770
Brentwood,	38.0	755
Summit, grade,	40.0	769
Belle Plaine,	45.6	731
High water in Minnesota river here,	45.6	725
Blakely,	49.9	734
High water here,	49.9	729
Cut at Rocky Point, 29 feet deep in till, $1\frac{1}{2}$ miles north of the line between Scott and Le Sueur counties, grade,	53.9	741
Low and high water here,	53.9	707–736

Elevations, Minneapolis & Saint Louis railway.

From J. B. Clough and Robert Angst, engineers, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
Bradford lake, grade, 875; water,	18.0	867
Summit, grade, at line between Hennepin and Carver counties,	18.7	877
Natural surface here,	18.7	907
Grade on trestle, 75 feet high and 450 feet long, crossing ravine, the east side of which is sand and the west side till,	19.1	848
Grade on second trestle, 65 feet high,	20.1	803
Foot of bluff, near Chaska,	22.0	754
Chaska, crossing the Hastings & Dakota railroad,	22.7	728
Carver,	24.7	722
Minnesota river, grade on bridge,	24.9	728
Minnesota river, low water,	24.9	690
Merriam or Sioux City Junction,	27.2	753
Jordan,	32.3	753
Sand creek, first crossing, grade, 766; water,	32.7	751
Sand creek, grade, 775; water,	32.9	760
Sand creek, grade, 786; water,	33.2	778
Sand creek, grade, 808, water,	33.8	800
Sand creek, grade, 829; water,	34.5	819
Helena,	36.3	886
Sand creek, grade, 872; water,	36.6	862
Raven stream, grade, 881; water,	36.8	866
New Prague,	42.6	973

Elevations on the Pacific division of the Minneapolis & Saint Louis railway.

From profiles in the office of Robert Angst, chief engineer.

	Miles from Minneapolis.	Feet above the sea.
Victoria,	25.0	963
Water-tank and windmill,	30.1	966
Waconia,	31.5	986
Marsh (survey 978–980),	34–34.7	981
Young America,	39.1	993
Crossing Hastings & Dakota railway,	40.2	976
Hamburg,	43.8	1000
Carver-Sibley county line,	45.0	995

Survey for the Hutchinson branch of the Minneapolis & Northwestern railway,
through northern Carver county and the southwest corner of Hennepin county.

From E. S. Alexander, engineer.

	Miles from Minneapolis.	Feet above the sea.
Christmas lake, northwest quarter of section 1, Chanhassen, about	17.1	932
Ridge south of Christmas lake,	17.1	1009
Lake Lucy,	18.2	955
Near middle of west line of section 3, Chanhassen, [This is on a narrow ridge, 20 feet above a tamarack swamp on the east and 15 feet above another on the west. The hills on each side are 60 to 70 feet higher than the swamps.]	19.3	1001
Minnewashta lake,	20.0	946
North line of Chanhassen township, in front of school-house No 59,	20.7	984
Virginia lake,	21.8	930
Lake Minnetonka,	22.7	928

From the outlet of Virginia lake the line of this survey extends $3\frac{1}{2}$ miles along the south side of lake Minnetonka and Halsted's bay, which are bordered by bluffs from 80 to 100 feet high.

Ridge between Halsted's bay and Six Mile creek,	26.5	954
Marsh of Six Mile creek,	26.6	930
Six Mile creek bottom,	26.7	924
500 feet north of the centre of section 20, Minnetrista, outlet of large cranberry marsh,	28.8	984
Water-shed between lake Minnetonka and Crow river,	29.2	992
Picture or Mud lake, sections 13 and 14, Watertown,	31.3 to 32.2	940
Near middle of north line of section 15, Watertown,	33.3	994
Bluff east of Crow river,	35.1	976
Crow river, top of Watertown dam,	35.8	927
Marsh, $\frac{1}{3}$ mile north of the southwest corner of section 8, Watertown,	36.7	937
Near the west side of the southwest quarter of section 11, Hollywood,	39.9	992
Ocean marsh, sections 7 and 8, Hollywood,	43.0	999
Line between Carver and McLeod counties,	43.9	1025

The elevation in feet above the sea of the Minnesota river, at its stages of low and high water, along the boundary of these counties, is approximately as follows:

Minnesota river.

	Low water.	High water.
At the southwest corner of Scott county,	709	738
At Blakely and Faxon,	700	729
At Belle Plaine,	696	725
Crest of Little Rapids,	692	720
Foot of Little Rapids,	690	720
At Hamilton,	689	725
Mouth, at Fort Snelling,	688	710

The last thirty miles of this river, from Little Rapids to its mouth, are held, at its lowest stage, as almost level back-water by the recent alluvial deposits of the Mississippi. Because of this dam across the mouth of the Minnesota river, its depth at low water along this extent of thirty miles is from 10 to 25 feet, quite uniformly averaging, except at the mouths of tributaries, about 20 feet.

Average elevation. The highest points in Carver county are the hills and swells of the moraine in Chanhassen and Laketown and thence southwesterly to Young America and Norwood, varying from 1,025 to 1,050 feet above the sea. The descent of the South fork of Crow river is approximately from 975 to 915 feet above sea in its course through the northwest part of this county. Estimates of the mean hights of the townships of Carver county are as follows: Chanhassen, 940 feet; Chaska, 790; Carver, 750; Laketown, 975; Dahlgren, 950; San Francisco, 840; Watertown, 975; Waconia, 980; Benton, 960; Hancock, 950; Hollywood, 1,000; Camden, 990; and Young America, 1,000. The mean hight of Carver county, derived from these figures, is approximately 955 feet.

In Scott county the highest elevations are also the morainic hills, which in Credit River, New Market and Cedar Lake, along the highest part of the moraine, have their tops 1,100 to 1,125 feet above the sea. The mean hights of the townships of this county are estimated as follows: Glendale, 850 feet;

Credit River, 980; New Market, 1,040; Eagle Creek, 850; Spring Lake, 950; Cedar Lake, 990; Jackson, 825; Louisville, 830; Sand Creek, 910; Helena, 950; St. Lawrence, 800; Belle Plaine, 930; and Blakely, 900. The average hight of Scott county is, according to these figures, about 925 feet above the sea-level.

Soil and timber. These counties have a very fertile soil, and produce abundantly all the ordinary crops of this latitude, including wheat, oats, barley, rye, corn, hay, potatoes, sorghum, flax, and garden fruits and vegetables. The thickness of the black soil, which is colored by the annual decay of vegetation, is commonly about two feet, but varies from one foot, more or less, on the morainic hillocks, to three feet or more in depressions and in many places on the bottomlands in the valley of the Minnesota river. In this valley the soil and subsoil are mainly recent alluvial silt, such as continues to be deposited by the high floods of every year. The terraces of modified drift upon the sides of this valley are sand and gravel, with occasional beds of clay. Their black soil is mostly one to two feet thick and scarcely inferior in fertility to the rich expanse of till, which covers all this district, excepting the Minnesota valley, where it has been cut through by fluvial erosion to the underlying strata of limestone and sandstone. Fully nine-tenths of the area of both Carver and Scott counties are desirable for cultivation, the only exceptions being the frequent small marshes, which are valuable for their hay, and the bluffs of ravines and valleys. The gently undulating or rolling surface gives the land almost everywhere excellent drainage; and the precipitation of rain is usually ample and pretty uniformly distributed through the seasons of spring, summer and autumn, coming in showers and in cloudy and rainy weather, which lasts through one, two, or three days, or rarely a week. In winter the snow is generally, during two or three months, from one to two feet deep.

Timber originally covered all this region, with the exception of the marshes and portions of the terraces and bottomland of the valley, which were prairie. This forest is part of the Big Woods of central Minnesota. By the early French voyageurs it was called the *Bois Franc,* because (excepting the red cedar, which occurs rarely)* it consists only of species that shed their leaves in autumn, including none of the evergreen pines, spruce, fir, and arbor

* Occasionally a white pine tree is found along the rocky river bluffs, in the *Bois Franc.*—N. H. W.

vitæ, which are mingled with the deciduous trees in the forest of the north and northeast part of the state. The Big Woods furnish little sawn lumber, as white pine, unrivaled for building purposes, is readily obtained; but several of the species of trees found here are suitable for the manufacture of furniture and wooden wares. The black walnut, formerly represented in the south part of these counties by occasional large trees, and still occurring scantily of small size, has here its northern limit. These woods are a large and dense growth, but their numerous marshes, the underbrush, and frequent patches of woodland grasses, afford considerable pasturage. In some places, as notably in section 13, Hollywood, the forest is destitute of the usual shrubs, and in their place the ground is thickly covered with smartweed. A great part of this timber has been already cleared off and the land brought under cultivation. The remainder is being gradually used for fuel, and by means of the railroads much of it is carried one to two hundred miles to the treeless prairies at the west and southwest.

Professor N. H. Winchell has recorded the following species of trees and shrubs observed by him in a journey across the northeast part of Scott county: bass, prickly ash, staghorn and smooth sumach, frost grape, sugar maple, soft or red maple, box-elder, wild plum, wild red cherry, choke cherry and black cherry, red raspberry, early wild rose, cockspur thorn, American crab-apple, June-berry, black currant, round-leaved cornel, panicled cornel and alternate-leaved cornel, wolfberry, common elder, high bush cranberry, white ash, green ash, slippery or red elm, American or white elm, red mulberry, butternut, bitternut, white oak, bur oak, apparently black scrub oak, hazelnut, iron-wood or hop-hornbeam, two or three species of willow, trembling American aspen or poplar, large-toothed aspen, cottonwood, and tamarack.

In southwestern Scott county, Mr. W. R. Salisbury, of Blakely, enumerates the trees and shrubs of that region, as follows: bass, box-elder, white elm, and iron-wood, generally abundant; cottonwood, soft or red maple, frost grape, and species of willow, very abundant on the bottomlands of the Minnesota valley; sugar maple, wild plum, American crab-apple, black ash, butternut, bitternut, bur oak, black oak, American aspen or poplar, prickly ash, smooth sumach, Virginia creeper, climbing bitter-sweet, choke cherry, red raspberry, rose, thorn, prickly and smooth gooseberries, wolfberry, elder, and hazelnut, common; black cherry, June-berry, white ash, slippery elm, hackberry, water beech, large-toothed poplar, black raspberry, high blackberry, black currant, and high bush cranberry, less common; red cedar, rare, upon exposed river-bluffs or lake-shores; also, black walnut and paper or canoe birch, mostly near streams, and tamarack in swamps, rare.

GEOLOGICAL STRUCTURE.

The formations to be described in this district are, in their order from the oldest to the newest, metamorphic rocks, and the Potsdam sandstone, penetrated by the salt-well at Belle Plaine; the St. Lawrence limestone, the Jordan sandstone, and the Shakopee limestone, belonging to the Calciferous or Lower Magnesian series; Cretaceous clay, occurring sparingly in hollows and seams of the Shakopee limestone near Merriam Junction; and the glacial and modified drift. The outcrops of the rocks that underlie the drift are confined to the Minnesota valley, where they are seen chiefly on the southeast and south side of the river, in Scott county, their only exposures in Carver county being at and near Little Rapids.

Metamorphic rocks and Potsdam sandstone. A well was drilled in 1870 and 1872 at Belle Plaine, on the bottomland near the depot, to the depth of 710 feet, with the view of obtaining brine suitable for the manufacture of salt. The details of the alluvial and drift deposits passed through are stated on a subsequent page, from the description of Prof. Alexander Winchell, who reported on this subject to Governor Austin in 1871, when the well, a six-inch pipe, had been sunk 210 feet, to the bed-rock. A later description, by Mr. P. M. Barker, superintendent of the work, gives 216 feet as the depths of superficial deposits, and states that the next 16 feet were a sandrock, supposed to be Potsdam, underlain by 10 feet of ochreous shale, the base of which was thus 242 feet below the surface. Samples of the preserved drillings from this depth to that of 411 feet were forwarded to Prof. A. Winchell, whose notes upon them are as follows:*

"At depth of 242 feet. Highly magnesian clays, purple and speckled with white, mostly without siliceous grains. One of the fragments contains a few quartzose grains, and has a decidedly metamorphic look. All the specimens resemble softened porphyries.

At 368 feet. A mass of granules or chips, similar to above, but more uniformly red and less unctuous All crush under the knife and exhibit a streak lighter than the mineral—sometimes grayish.

At 380 feet. Fragments still more like (242–282) but less unctuous. A broken crystal of calcite.

At 385 feet. Fragments (nearly a cubic inch) of a rock, composed apparently of reddish clay and a

* Second annual report, p. 80.

white mineral, like magnesia or kaolin intimately mixed, the white mineral tending in places to veins.

At 390 feet. Fragments like (380) but with more calcite, and one slightly polished fragment of glassy quartzyte.

At 398 feet. Almost identical with (390). From the same depth, however, is a lump of adhesive clay, which is evidently produced by grinding up rock like (242–282).

At 400 feet. Essentially like (242–282).

At 405 feet. Essentially the same, with one fragment of quartz.

At 409 and 411 feet. Same.

These rocks are very remarkable. All the samples are argillo-magnesian, mostly fine-grained, unctuous, sometimes lined and frequently speckled with a white mineral like magnesia or kaolin. They present almost no grains of quartz, but sometimes inclose crystals and seams of calcite. The color is reddish and purplish. Viewed without a test of hardness, they look like vitreous prophyry. I am led to think they represent the formation" [which is believed to belong to the Potsdam epoch] "known to outcrop at New Ulm and in Pipestone county. These clays, in fact, are substantially the catlinite or 'pipestone' so well known in that county."

Samples of the drillings below the depth of 411 feet were reported by the state geologist. Prof. N. H. Winchell, to have the following external characters.*

"At 420 feet. Ferruginous quartzyte, with a considerable admixture of light-colored, softer, apparently talcose fragments. The quartzyte is hard and very impure. The talcose fragments are either nearly white or speckled with rusty and black spots. There are also in the drillings pieces of calcite, a soft, greenish substance that may be silicate of iron, and occasional fragments of translucent quartz, either white or slightly tinted with yellow or with green.

At 430 feet. A mixture of dark brown or reddish silicates, strongly ferruginous, with slight traces of mica and some pieces of calcite. Some of it appears conglomeritic or tufaceous. It is slightly unctuous in the fingers, and some of it is real iron ore. The light-colored pieces of the last (420 feet) are rarely seen. There are in it occasional greenish pieces of quartz. It is evidently a metamorphosed sedimentary rock.

At 440 feet. A Ferruginous, unctuous shale, with very little grit. It sometimes is spotted with a white substance about as hard as talc, which has a greasy feel. This white substance seems to be the same as mentioned in the foregoing. It is sometimes minutely disseminated among the ferruginous portions. When rubbed in the fingers, a rusty or irony stain covers the whole. Some of this is plainly siliceous and micaceous.

At 450 feet. About the same as at 430 feet, but darker colored and less firm in the fingers. It is plainly micaceous.

At 460 feet. Dark greenish brown, micaceous silicates; hard and compact. Not evidently unctuous No feldspar is discernible.

At 470 feet. A talcose, ferruginous shale, of a reddish-brown color, with occasional pieces of greenish silicate. In this lot there are also several pieces of evident flesh-colored feldspar.

At 480 feet. A mixture of ferruginous silicates with some mica and talc and calcite; with occasional pieces also of the soft, greenish substance mentioned at 420 feet. The last is softer than calcite. The general color of the whole is dark red or brown.

At 490 feet. The same as at 480 feet.

At 500 feet. The same as at 480 feet.

At 510 feet. The same as at 480 feet, but more friable, apparently, as the sample is in the form of sand. There are also in this lot several large fragments of ferruginous shale, which have a greasy feel, probably broken from the underlying beds by the bucket and brought up with the drillings.

At 520 feet. A very dark, ferruginous mixture of the various silicates, including the light-green soft substance, resembling silicate of iron. This last also resembles talc, and is as soft.

*Second annual report, p. 82.

At 530 feet. A red arenaceous shale, with some talc and calcite, and also fragments of flesh-colored feldspar.

At 540 feet. The same as at 530 feet.

At 550 feet. Fragments of dark red, coarse shale, like the last, and of a darker slightly greenish shale, that appears as if originally amygdaloidal, the cavities having been subsequently filled by the soft green substance mentioned at 520 feet. This latter mass is sometimes closely mixed with small geodes with rusty exterior.

At 570 feet. A dark brown shale, like the dark shale in the last, closely mingled with the soft, greenish (silicate of iron?).

At 580 feet. The same as at 570 feet.

At 590 feet. The same as 570 feet, but showing a little more red, and also evident pieces of calcite.

At 600 feet. The same as at 590 feet, but with increasing quantities of the greenish, soft substance.

At 614 to 620 feet. A mixture of the various silicates with considerable iron, the quartzitic characters being much more evident than at 570 feet. It is also firmer—hardly a shale.

At 620 feet. The same as the last.

The well is said to be 710 feet in depth, and the opinion is prevalent that there was no change from 620 feet to that depth. As there are no preserved samples below 620 feet, it is also probable there was no marked change in the rock. If that be correct, it gives a thickness of 292 feet of rock, which may all be classed as a siliceous, unctuous shale, highly ferruginous, and sometimes amygdaloidal, varying to micaceous quartzyte. It seems to be a metamorphosed sedimentary rock, lying below both the St. Croix sandstone and the Potsdam sandstone. . . . Hence the bottom of the well is in the Huronian slates and schists, but has not yet struck the granite. In this statement it is presumed that the interval unrepresented by drillings . . . is filled . . by the same general class of rocks."

St. Lawrence limestone. The lowest formation of the Lower Magnesian group exposed in this valley is a yellowish and reddish massive dolomite, named the St. Lawrence limestone, from the township in Scott county where extensive ledges of it are first found in ascending the river. Below its outcrops which are quarried in this valley at Judson and Hebron, ten miles west of Mankato, its next exposure is at Rocky Point in Scott county, near the middle of the west side of section 30, Blakely, at the extremity of an eastward bend of the river. The section here at the time of my exploration was obscured by the falling down of the overlying drift, but a good description of it is given by Dr. Shumard in Owen's report, as follows: "The rocks at this place are exposed to the hight of eighteen feet above the water-level. In the ascending order there is, first, ten feet of rather thick-bedded salmon-colored magnesian limestone, somewhat cellular, the cells being coated with carbonate of lime; then succeeds two feet of magnesian limestone, in layers varying from a half inch to two inches in thickness, succeeded by six feet of intercalations of sandstone and magnesian limestone, on which rests the drift, which has a thickness of over one hundred feet." These beds appear to be the top of the St. Lawrence limestone and the base of the Jordan sandstone. Within three miles to the north, in Jessenland and Faxon, Sibley county, are two or three small and low outcrops of this limestone which have been slightly quarried. At Raccoon rapids, about a half mile southwest from Rocky Point, and again a mile farther west, ledges of this rock are only thinly covered by its fragments and the alluvium of the bottomland.

In St. Lawrence, ten miles northeast from the foregoing, this limestone outcrops occasionally along a distance of some two miles, from the southwest quarter of section 28 northeasterly to the east part of section 22, having its top about 45 feet above the river. It is nearly level in stratification, in beds from 2 to 18 inches thick. The color is buff, reddish, or yellowish gray, usually with frequent green specks. In composition it is a siliceous magnesian limestone. It has been considerably quarried, and supplies good building stone. A vertical thickness of about 15 feet is seen in quarries and natural exposures; and wells here have drilled into it 24 feet, without reaching its base. At Enos Bragg's, near the center of section 28, a ledge of sandstone or a sandy limestone occurs at about the same level with the quarries, but probably belongs to a higher geological horizon, the base of the overlying Jordan sandstone.

Prof. N. H. Winchell says of this formation at the quarries in the northeast quarter of section 28, St. Lawrence:* "It is harder than the Shakopee limestone, evenly bedded, quartzose and specked with green. These green specks have somewhat the appearance of coming from metamorphism, yet they are caused by little rounded masses, which, if harder, would seem to have been water-worn and deposited with the sedimentation. They are, however, rather soft, cutting like talc. They exactly fill the cavities in which they lie. In some small portions they almost make up the bulk of the rock, which then has a green, compact appearance, as if hornblendic. While the rock is evidently calcareous and magnesian in some parts, and almost destitute of these green specks, it is also siliceous and sharply crystalline. . The section here exposed is as follows:

1.	Beds two to four inches, with shaly partings and green specks,	3 feet.
2.	Beds fourteen to eighteen inches, hard, siliceous, occasionally porous from crystallization, specked with green, showing crystals of brown spar; a good building stone,	4 feet.
3.	Somewhat ferruginous, hard and crystalline, less porous than No. 2,	2 feet.
4.	Beds irregular, specked with green, and showing green surfaces,	4 feet.
5.	Band of greenish shale, sandy,	6 inches.
6.	Beds two to four inches: magnesian limestone; seen about	1 foot.
	Total,	14½ feet."

A chemical examination of this rock is reported by Prof. S. F. Peckham:† "This stone consists of a hard, siliceous, magnesian limestone, containing sufficient iron to give it an ocherous shade of color with yellowish streaks. It also contains angular grains of quartz and small grains of a green mineral quite uniformly distributed through the rock. These grains are of all sizes from that of a large pin's head to those of scarcely perceptible dimensions. They are irregularly spherical in form, sometimes slightly flattened or elongated. Cold commercial hydrochloric acid dissolves all of the constituents of the rock except the grains of quartz and the green grains. By sifting and careful sorting, the largest of the green grains may be obtained quite pure. The specific gravity of these grains is 3.634; hardness, about 2.0. B. B. in fusible, becoming brown from oxidation of iron. In the closed tube gives water, becoming more or less oxidized. The following are the mean results of three analyses: Silica, 48.20 per cent.; ferrous oxide, 27.09; alumina, 6.94; potassa, 7.54; soda, 1.02; water, 8.72. These characteristics and results give a variety of glauconite not decomposed by hydrochloric acid."

* Second annual report, p. 152.
† Fifth annual report, p. 61.

At Jordan, three miles east from St. Lawrence, wells encounter the St. Lawrence limestone, pinkish buff in color and very compact and hard, lying directly beneath the soft and friable Jordan sandstone. At the upper brewery the well was 12 feet deep, 10 feet in sandstone and 2 feet in limestone. The well of the lower brewery, 11 feet deep, was dug 6 feet in sandstone, and then 5 feet in this very hard limestone. Below this it was drilled 25 feet, all the way in limestone, which was thought to grow harder; its base was not reached. The limestone also occurs in the bed of Sand creek, at the pier of the private bridge in front of the lower brewery. All these exposures of St. Lawrence limestone in the Minnesota valley probably exhibit its upper portion.

Jordan sandstone. Next above the last is a coarse-grained sandstone, white or light gray, or often somewhat stained with iron-rust. It is usually soft and crumbling, so that it is readily excavated with a shovel; but some of its beds, quarried at Jordan, yield stone sufficiently durable for the construction of large mills and bridge masonry. It becomes harder upon exposure to the air, and its ledges sometimes have an indurated surface while they are quite friable within. The stratification is level or nearly so, in beds that vary from six inches to three feet in thickness. While each of these layers is plainly horizontal, its lamination is frequently oblique, being inclined 5° to 20°. This structure is the same with that often seen in recent sand-deposits, where the material was spread and arranged by strong currents. The direction of this inclination is variable, and seems to indicate the action of tides or waves in water of no great depth.

At Jordan this sandstone forms numerous outcrops for three-fourths of a mile along the valley of Sand creek. It is horizontally bedded, and the exposures are between 35 and 75 feet, approximately, above the river. Here and in several outcrops of this rock occurring within six miles northward in the Minnesota valley, the overlying member of the Lower Magnesian limestone is wanting.

The general section in the vicinity of Jordan is described, in descending order, by Prof. Alexander Winchell, as follows:*

1.	Sandrock, buffish, quite ferruginous, thick-bedded, seen at the mill,	6 feet.
2.	Sandrock, ferruginous, thin and irregularly bedded, friable and disintegrating, with many ferruginous seams, crusts, and concretions. In the quarry,	3 feet.
3.	Sandrock, irregularly whitish or ferruginous, heavy-bedded, obliquely and beautifully banded with iron streaks and laminæ. In quarry,	12 feet.

* Report of a geological survey of the vicinity of Belle Plaine, 1872.

4. Sandrock, buffish, similar to No. 3, but thinner-bedded. In the quarry, 8 feet.
5. Sandrock, hard and ferruginous above, soft, friable and buffish red below. Falls of Sand creek, 10 feet.
6. Sandrock, whitish, compact. In the beer vaults, seen, 12 feet.

The state geologist, Prof. N. H. Winchell, adds:* "Although the foregoing section makes up a thickness of 51 feet for this sandstone as exposed at this place, the observations of the survey do not warrant the assignment of that aggregate thickness to the outcrops there, some of the localities named being regarded as on the same geological horizon. The general uniformity of characters makes it difficult to judge how much of the bedding at one place may be included in the outcrop at another; but twenty-five or thirty feet would probably cover the thickness exposed."

In the north edge of Sand Creek and the south part of Louisville, four to six miles north of Jordan, extensive outcrops of this sandstone rise from the bottomland. In section 4, Sand Creek, and section 33, Louisville, it makes a terrace-like tract, 30 to 50 feet above the river, and about 200 feet lower than the bluff of till at its east side. On the north part of this terrace, where the public road crosses Van Oser's creek, the sandstone has been tilted by some local disturbance which does not generally affect this formation. Prof. N. H. Winchell writes that, at this place, "it has a dip of 10 or 15 degrees toward the W. N. W. About twenty-five feet can here be made out in passing along the stream from a short distance above the road to the crossing of the St. Paul & Sioux City railroad. It is in heavy beds and is coarse-grained. It is full of seams and checks, presenting some appearance of dip in different directions. Some of the seams, or lines of apparent bedding, run nearly perpendicular, but they do not have a constancy that shows dip. The operation of the stream is such as to bring out the bedding, by the wearing away of the softer layers, so as to indicate dip in the direction already stated."

Professor Winchell continues: "Near the railroad bridge over Van Oser's creek, and in the public road, this sandstone is conglomeritic and broken. It shows the effect of heat. The bedding is disturbed and even fractured, the openings having been again filled with coarser materials and some pebbles. Some parts of it are highly ferruginous, so as to make an impure iron ore which is black. These characters, however, are confined to a very small area, not being seen over more than three or four square yards, making a mound-like prominence that rises two or three feet above the level of the rest of the bedding, which is bare for some rods about.

"About a mile above the crossing of Van Oser's creek, the St. Paul & Sioux City railroad cuts through sandstone which may be somewhat below the beds last mentioned. The upper part of this may be regarded as belonging in the section at the creek. This cut is composed of the following parts:

1. Hard (yet within friable) sandstone, in one bed, of a reddish color, 3 feet.
2. Fine, incoherent, white sandrock, massive; seen five feet, may amount to 10 feet.

"Directly east of this cut, across the public road, No. 1 above, which is supposed to be the same as the sandstone seen in Van Oser's creek, outcrops so as to show 15 or 20 feet. It causes a considerable knoll, where huge blocks four or five feet thick are checked loose by the weather and removed from the general mass. This" [near the north line of section 4, Sand Creek] "is a favorable place for quarrying."

General G. K. Warren's map of the Minnesota valley in this vicinity †shows that section 32, Louisville, and the edges of the adjoining sections, contain several island-like areas of Jordan sandstone, the two largest of which are each about a mile long, from south to north or northwest, and elevated 35 to 45 feet above the river. They are surrounded by water-courses, swamps, and low, alluvial land; and are separated by a swamp through which Sand creek sends a part of its waters northward to the Minnesota river, flowing at one place, on the west side of the eastern island, under a natural bridge of this weathered and eroded sandrock. "These high, detached islands in the valley," as Gen. Warren remarks, "show there must have been a cataract at this

* Second annual report. p. 149.

† An essay concerning Important Physical Features exhibited in the valley of the Minnesota River, and upon their signification. *Engr. Dep., U. S. Army:* 1874.

point in the course of the ancient river," which was "divided into at least three channels."

A short distance farther west, outcrops of this sandstone in the present channel of the Minnesota river form the Little Rapids. These are two and a half miles south of Carver, in the southeast quarter of section 31, of Louisville on the east and San Francisco on the west. At the time of my visit to this locality, August 25, 1879, the fall at the lower rapid was two feet, very nearly. The sandstone is here visible only in the bed of the river, which it reaches across, from east to west, this distance being about twenty rods. It dips slightly, one or two degrees, to the south-southwest. Though somewhat hard on the surface, it is softer and friable within, having the usual character of this formation. Its exposure is nearly level, and rises only one or two feet above the water. About a quarter of a mile southeast from this, up the river which turns at a right angle between these points, is a second rapid, where another low and nearly level ledge of this sandstone crosses the channel from north to south, causing only a ripple in the river at the time of my visit, with a descent of not more than one or two inches. At the lowest stage of water the fall in these rapids, according to Gen. Warren's survey, is one foot and two and a half inches. The sandrock at each of these rapids is cut by nearly vertical joints, which extend parallel, from one to six feet apart, across these outcrops, bearing S. 40° W., with reference to the true meridian. At a second bend of the river, about an eighth of a mile above the upper rapid, this sandstone is again exposed along a distance of some fifteen rods in the east bank of the river, rising three to six feet above the line of low water.

The only other exposure of the bed-rock known in Carver county is reported by Dr. Shumard, one mile above Little Rapids, "on the left bank of the river, and a few hundred yards from the shore," where this Jordan sandstone was observed, overlain by a magnesian limestone.

In the southeast quarter of section 20, Louisville, Mrs. M. A. Spencer's well went into this sandstone, after passing through limestone more than twenty feet. The lowest point in this valley at which the Jordan sandstone is exposed to view is Mrs. Spencer's quarry, about a third of a mile farther east and one and a half miles southeast from Carver. Here the overlying limestone has a thickness of about 30 feet, and 4 feet of the Jordan sandstone is visible below it, their junction being some 25 feet above the river.

Lower Magnesian limestone.—The north part of Scott county, in Louisville, at Shakopee, and eastward to Hamilton, has frequent outcrops of the next higher member of the Lower Magnesian group, named Shakopee limestone from the town at which it is first found well exposed in ascending the Minnesota valley. This formation, with the underlying Jordan sandstone, is also conspicuously exposed southward in Le Sueur, Nicollet, and Blue Earth counties, along this valley, and in the valleys of the Blue Earth river and its tributaries. It is a magnesian limestone of buff color, often mottled in alternate red and yellow tints. The stratification is nearly level in beds from a few inches to three feet or more in thickness. In some places, as at Kasota, in the asylum quarry at Saint Peter, and at Mankato, a part of these beds are compact and supply an excellent stone for every purpose in building or monumental work; but generally this rock is much broken by little hollows and crevices, and is of unequal texture, some portions being especially sandy or coarse in grain, or having contorted and obscure lamination. It is burned extensively for lime at Mankato, Caroline station, Louisville, and Shakopee. The only observation of any rock lying upon this limestone in the Minnesota valley is at the asylum quarry, where Prof. N. H. Winchell found it covered by two feet of white friable sandstone, with a thin strip of green shale about midway in it. This is supposed to be either the New Richmond beds or a Cretaceous deposit. The thickness of this limestone in the Minnesota valley varies from about 20 feet at Saint Peter,* to nearly 100 feet, as shown by wells, within one and a half mile south of Shakopee.

A thin layer of this limestone, according to Mr. Wardell Spencer, remains in patches on the top of the island-like outcrops of the Jordan sandstone in section 32, Louisville. Less than a mile to the northeast, on the Minneapolis & St. Louis railway, about sixty rods south of Merriam or Sioux City Junction, a cut ten feet deep is made in the lower beds of this limestone, which is here much blackened by irony stains. This rock has frequent exposures and forms a rough surface, mostly covered by drift with numerous boulders, for a mile thence northwestward to Mrs. Spencer's house and quarry, before mentioned.

At the Louisville lime-kilns, about three-fourths of a mile north of Merriam Junction, this limestone is described by Prof. Alexander Winchell,† as forming "a bluff facing west, and re-appearing in an outlier a quarter of a mile nearer the river. The rock is very irregularly stratified, and varies much in hardness and color. The prevailing colors are pinkish and buffish. Some of the layers are sandy, others magnesian, others ochery and ferruginous, others purely calcareous. Some portions are quite vesicular and abound in small crystals of brown spar. Thirty-six feet are exposed in the quarry, and below this a

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* See the fourteenth annual report, pp. 13 & 325. Mr. Upham has here included in one description what in other places appears as two limestones. The Shakopee limestone, the uppermost of these, is seen at the Louisville quarries where it is used for quicklime. The bluff which it there forms rises from seventy-five to a hundred feet above the flat on which Merriam Junction is situated. This lower flat, extending to the river, is composed of the lower limestone, the same that is seen at St. Peter and Kasota, mainly in heavy beds, and useful for building stone. The upper beds swing eastward from the Louisville lime-kilns, in their strike, causing a marked bench-line, and enter the outer-bluff of the valley, disappearing from view entirely, until they return with a feebler representation at Caroline station and Mankato. [N. H. W.]

† Report of a geological survey of the vicinity of Belle Plaine.

well has been sunk 38 feet in the limestone, making a total of 74 feet. Below the limestone the well extended 24 feet in sandstone."

At Shakopee the limestone rises from the river's edge to a hight of 50 feet, its upper 20 feet being quarried for lime. Its outcrops are occasionally seen along a distance of one or two miles both to the east and southwest from the lime-kilns, which are in the west part of the town. The section exposed here by quarrying is described by Prof. N. H. Winchell, as follows:*

1. Can hardly be separated from the rest, but seems more shattered and thinner bedded. It also contains some chert. It is crystalline and porous, with no regularity of bedding, 6 to 8 feet.
2. An irregular layer of sandstone, or of very sandy limestone, used for building stone, making some good faces; beds about 8 inches, 2 feet.
3. Rather heavier beds of hard gray limestone, of a maguesian texture and feel. These beds are sometimes cracked and checked in all directions, and pass into fine-grained patches, and then thicken again. These thin beds are not infrequently wavy or contorted within the mass. Purgatories are also common in the face of the bluff through all the parts, 10 to 12 ft."

"The bedding is much confused and almost obliterated by chemical and other metamorphic agencies. The stone is very rough and very often a true breccia. It is somewhat arenaceous, and also argillaceous. Some small, shapeless cavities are filled with a greenish shale, which, if indurated, would be like some flinty spots often seen in the same formation, as at Winona. Some of this shale is so hard as to have conchoidal fracture, and some is so soft as to be like wax or putty in the fingers. It varies through different shades of green and blue. It seems to be intimately blended in texture with, and insensibly passes into, the compact limestone of the most fine-grained portions of the quarry. It is not a common ingredient. Some other cavities are lined with incrustations of mammillated and drusy quaftz.'

Beneath the terrace of sand and gravel, commonly called "Shakopee prairie," south and southeast of this town, the limestone is found at a depth of 40 or 50 feet, its top being about 100 feet above the river. Water is obtained in the wells on this terrace only after drilling 60 to 75 feet or more in the limestone. Thus the well at Hon. H. B. Strait's residence, a mile south from the centre of Shakopee, 122 feet deep, is soil and sand, 8 feet; clay, 30; limestone, 84, its last five feet being light gray in color; water abundant, rising nine feet. J. A. Wilder's well, half a mile northeast from the foregoing, 112 feet deep, is soil, 2 feet; yellowish stratified clay, 5; sand and gravel, interstratified, coarsest below, 38; hard limestone, 61; quicksand and sandstone, 2 feet, containing plenty of water, which does not rise; underlain by hard, cherty limestone, into which the well was drilled 4 feet. These are within the incorporated limits of Shakopee. Amos Riggs' well, one and a half miles southeast from these, in the S. E. ¼ of section 18, Eagle Creek, is 115 feet deep, in order as follows: soil, 2 feet; sand and fine gravel, 38; very coarse gravel, with pebbles up to 1½ feet in diameter, 10 feet; rotten, sandy limestone, picked, 5 feet; limestone drilled, nearly all alike, 60; water comes abundantly at 107, not rising.

About a half mile south from Hon. H. B. Strait's, a well sunk by Matt

* Second annual report, p. 140; and first annual report, p. 82.

Huss, in the south edge of section 12, Jackson, in a depression of the prairie 30 feet below the general level, is 90 feet deep, and went through soil, 2 feet; sand and gravel, containing pebbles up to one foot in diameter, 13 feet; yellowish till, 3 feet; limestone, decayed and easily picked, 4 feet; and hard limestone, drilled, 68 feet. Water, at first bringing sand with it, was found 1½ feet above the bottom, but does not rise in the well. The foot last drilled, below this vein of water, is very hard, cherty limestone. Copper is said to have been found in this well just above the water, small fragments of it being brought up in the work of drilling; which led to sinking a shaft near by, but this was abandoned at the depth of 45 feet.

The greatest thickness recorded of the Shakopee limestone in the Minnesota valley is found in John Ederd's well, 136 feet deep, a half mile south from the last, near the centre of section 13, Jackson. Stratified gravel, sand and clay extend here 40 feet, below which the remaining 96 feet were limestone, hard to the bottom, but containing veins of water in its last five feet, which brings in sand and rises sixteen feet.*

Four miles east of Shakopee, on land of Thomas Durose, in section 3, Eagle Creek, this limestone outcrops, and has been slightly quarried, beside a little creek, north of the road and near the river, above which its hight is 10 to 15 feet. About six miles farther east, at and near Hamilton, are the lowest points at which the Shakopee limestone is seen in the Minnesota valley. Here it occurs for about 50 feet along the bottom of the race-way of Quinn Brothers' mill, at a hight of 20 or 25 feet above the river. A mile west and again a mile east of Hamilton, abundant fragments of this rock strow small areas of the bottomland, indicating that solid ledges of it rise nearly to the surface. Farther east this limestone sinks below the level of the river, and the bluffs of Fort Snelling and its vicinity are composed of the overlying St. Peter sandstone capped by Trenton limestone.

It is interesting to note the nearly level position of these very ancient strata, which have scarcely suffered any disturbance since their deposition. Alternately beds of limestone and sandstone were accumulated upon the floor of the paleozoic sea, and they have been lifted 700 to 1,000 feet or more with-

* The thin sandstone stratum mentioned in Mr. Wilder's well, underneath 61 feet of limestone, and underlain by a hard cherty limestone, is the representative of the Richmond sandstone. It is probable that the horizon at which the other wells get water and sand was in the same sandstone, this being at the place where these wells are located, about the level of the water of the Minnesota. Mr. Ederd's well seems to indicate a thickness of 91 feet for the Shakopee beds, and five feet for the Richmond sandstone. [N. H. W.]

out being broken or tilted. The hight above sea of the base of the Shakopee limestone where it has been observed within the Minnesota valley, is at Mankato, 780 to 795 feet; at Kasota, about 775; at Saint Peter bridge, about 750; at Ottawa, 770; and at Louisville, about 720. The distance included is forty-five miles in a straight line.

No fossils have been discovered in these formations of the Lower Magnesian series in Carver and Scott counties.

Cretaceous clay. At the cut of Shakopee limestone mentioned as occurring on the Minneapolis & St. Louis railway close south of Merriam Junction, scanty deposits of red and yellow clay were observed in cavities and seams of that rock, evidently similar in character, position, and origin, to the deposits of clay, supposed to be of Cretaceous age, which fill hollows of the Shakopee limestone in this valley at Ottawa, Saint Peter, Kasota, Mankato and South Bend.

Glacial and modified drift. In treating of the surface features of these counties, a former portion of this chapter has described the material and topography of their drift-sheet. This consists mainly of till, inclosing occasional layers or veins of gravel and sand whence water is often obtained in large amount and rises several feet in wells. It is rolling and hilly in contour throughout the morainic belt on the east, but only moderately undulating and sometimes nearly flat on the west. The average thickness of this sheet of drift is probably about a hundred and fifty feet. It everywhere covers the bed-rocks of these counties, except in the Minnesota valley, which is excavated 200 to 240 feet below the general level, in numerous places exposing the rocks that underlie the drift, to hights 50 to 75 feet above the river.

The morainic belt in Scott county and the adjoining western part of Dakota county has a width of about fifteen miles. Upon this area the eastern border of the ice-lobe that covered western Minnesota in the last glacial epoch seems to have been maintained without important movements of advance or recession during the time in which the western boundary of this glacial lobe, driven back in the final melting of the ice-sheet, had receded from the Coteau des Prairies to the east side of Big Stone lake, and while its extremity was withdrawn from Des Moines to Elysian and Waterville in Le Sueur county. The Altamont, Gary, Antelope, Kiester and Elysian moraines, described in the first volume of this report, were accumulated at the farthest limit and successive stages in the recession of the ice, before any considerable change took place in this part of its eastern boundary. But when the continued melting caused the ice-lobe to recede from the Elysian moraine, its length was diminished forty miles, the southeast end of the ice being withdrawn across Le Sueur and Scott counties and the Minnesota river. Its next halt seems to have been made where the morainic belt exhibits a notable expansion from Chaska and lake Minnetonka southwestward to Waconia and Young America. This *sixth, or Waconia, morains* is also recognizable farther southwest, about High Island lake at New Auburn, in Sibley county; but its course from Carver county westward, probably keeping on the northeast side of the Minnesota river and reaching to Big Stone county, though believed to be traceable by careful topographic study, is nowhere conspicuous and has not been mapped.

Limited deposits of modified drift are found rarely on the surface of the sheet of till. In the southeast quarter of section 12, Hancock, in Carver county, a section in a knoll beside the road showed eight feet of gravel overlying the ordinary till or boulder-clay. A little farther east, in the southwest corner of section 7, San Francisco, another cut beside the road exhibited gravelly, black soil, 1 foot; changing into yellowish and ferruginous gravel, which holds pebbles up to six inches in diameter, 2 feet; gray clay and fine gravel, interstratified in contorted but approximately level layers one to three inches thick, 1½ feet, extending three rods, thinning out at the east; and gray gravel, containing pebbles up to one and a half inches in diameter, exposed 1 foot vertically at the base of this excavation and extending below. Within the next three miles eastward, deposits of gravel and sand, 5 to 10 feet or more in thickness, having a moderately undulating or rolling surface, similar to that of the till, are seen at many places before coming to the nearly level terrace of modified drift which reaches through the east part of San Francisco, along the northwest side of the Minnesota valley. In the northeast quarter of section 33, Laketown, about a third of a mile north of Windmill hill and some 40 feet below its top, a cut six feet deep in stratified gravel and sand was seen beside the road, but the region all around is moderately rolling till. All these deposits of modified drift are believed to be kame-like in their origin, having been laid down by streams flowing from the melting ice-sheet.

Very remarkable beds of sand and gravel are found at Prior Lake station and eastward. The railroad well at this station went 210 feet; through soil, 2 feet; sand, 26 feet; clay, 3 feet; sand, 175 feet; and fine gravel, containing pebbles up to two inches in diameter, 4 feet, and reaching lower; finding no water. About an eighth of a mile northeasterly from this, Mr. Schmokel's well, 85 feet deep, was soil, 2 feet; yellowish till, 10 feet; and sand and gravel, coarsest near the bottom, 73 feet, obtaining a good supply of water, which stands two or three feet deep. A second well of the same owner, about two hundred feet west of the last, was 65 feet deep, being soil, 2 feet; yellow till, 10; sand, 12; blue till, 30; and fine gravel, 11 feet, yielding no water. Sand and coarse gravel, with pebbles up to six inches in diameter, extend thence at least one and a half miles eastward, forming swells and hills up to 50 feet in hight, with a prevailing trend to the east-northeast. Markley lake, about a third of a mile long and ten to twenty-five rods wide, also trending east-northeast, lies in a depression of these deposits. The origin of this modified drift in a region principally occupied by morainic accumulations of boulder-clay or till, seems again to be referable to deposition by the waters produced by glacial melting. It seems probable that, during the long epoch when the ice-sheet, moving slowly eastward, was terminated at this morainic belt, the discharge of its summer melting converged here from a large area on the west. Six to eight miles farther east, at the eastern side of this moraine, the avenues by which drainage from the ice-sheet took place beyond its border are very noticeable topographic features, being valleys from a half mile to one and a half miles wide, which extend east and southeast from the east ends of Crystal lake and Lakeville or Prairie lake, in Dakota county. The beds of these ancient water-courses are level modified drift. The one beginning at Crystal lake includes the greater part of sections 33 and 34, Lebanon, and sections 2, 3, 11, 12 and 13, Lakeville, continuing southeasterly to the Vermilion river. This valley is called the "low prairie," in contrast with the "high prairie" of similarly flat modified drift, which at its western edge is 40 feet above this broad channel, and reaches from it twelve miles east, by Rosemount to Rice Valley, another water-course of this glacial period, and to the Vermilion river in the northeast part of Vermilion township. On the southwest side of the valley that starts from Crystal lake, a tract of moderately rolling till, 50 to 75 feet high and three to five miles wide, divides it from the outlet of glacial melting which begins at Prairie lake and reaches easterly by Fairfield and through the northeast part of Eureka to Farmington. It is evident that the large glacial river

which deposited the sand and gravel of Prior lake and its vicinity flowed eastward into Dakota county, and that beyond the morainic belt, its course was by Crystal or Prairie lake to the Vermilion river along one or the other of these old water-courses.*

Boulders occur very plentifully one and a half to two miles east of Shakopee, between the railroad and the highway, on land 25 to 40 feet above the Minnesota river. They are the cause here of a remarkable ridge which rises four to six feet above the general level, is about three rods wide, and reaches fully sixty rods in a straight east-southeast course. This is a distinct and continuous ridge, sprinkled with a multitude of boulders of all sizes up to five feet in diameter, which cover from a quarter to a half of its surface, while the land on each side appears to be modified drift and has few or no boulders. More than ninety-nine hundredths of the boulders are granite, syenite, gneiss, and crystalline schist. Rarely blocks of obscurely fossiliferous limestone, such as outcrops in Manitoba and has no nearer exposures, are seen with the foregoing, the largest piece noticed being four feet long. These rock-fragments have forms that characterize the upper part of the till, being angular or only rounded as commonly is done by weathering, and seldom exhibiting any traces of glaciation. Occasional knolls, short ridges, and hillocks of drift, inclosing very abundant boulders, also occur in the vicinity of this ridge, especially toward the northwest. The only large boulder seen near is granite and lies an eighth of a mile southwest from the west end of the ridge. It was originally 15 feet in diameter, and is now broken into three pieces.

At other places in this valley, eastward to Hamilton, and southwestward in Louisville and St. Lawrence, boulders are frequently abundant where till or the old stratified rocks reach to the surface. They are probably also sprinkled in equal numbers upon the adjoining parts of the valley, but are hid from sight by the overlying alluvium and modified drift. In the erosion and removal of the glacial drift and its terminal moraine where this valley is, the transporting currents of water have left these heavy rock-fragments, which occur no more plentifully than in the total thickness of the till and moraine of the adjoining region, in which they are less conspicuous because distributed through the drift from its surface to its bottom, a depth varying from 150 to 200 feet or more.

Two or three small pieces of copper, brought by ice, probably from the

* See the report on Dakota county for further description of these old valleys.

region of lake Superior, were found in the drift in grading the railroad between Carver and Merriam Junction.

The bluffs of the Minnesota valley frequently exhibit modified drift interbedded, sometimes in deposits of large extent and thickness, with the till, which makes up the principal mass of these bluffs and of the drift-sheet. This is illustrated by the cuts made for the Minneapolis & St. Louis railway, where it descends into this valley in the southeast part of Chanhassen. On the road leading northwest from Carver, about three-quarters of a mile from the town, at a hight approximately 200 feet above the river and some 50 feet below the top of the bluff, a section shown by the recently undermined bank of the ravine on the northeast side of the road, was stratified gravel, 8 to 12 feet thick, yellowish, gray, and brown in different portions, containing pebbles up to six inches in diameter, notably ferruginous in its lowest foot; underlain by imperfectly stratified, pebbly clay, yellowish, exposed 15 to 20 feet vertically and reaching lower, resembling till, except that it shows nearly level layers which are alternately moist and dry, or some of them more sandy or finer than others, but all inclosing gravel stones up to six inches in diameter, while a boulder two feet in diameter is embedded in the lower part of this clay. The upper two feet of the overlying gravel is black soil, and in this, just below its top, another boulder of similar size was noted. The railroad cut in the base of the bluff at Rocky Point, in section 30, Blakely, exposes the following section on its east side: soil, 2 feet; yellowish till, 13 feet; dark bluish till, 30 feet; underlain by yellowish sand, seen to the thickness of 2 or 3 feet, and reaching lower; the last extends along the bottom of this cut its whole length of about 300 feet; it is nearly local in stratification and in the definite line which divides this modified drift from the till above, characters which indicate that these deposits lie in their original place and have not been disturbed and caused to fall by the erosion of the valley. The top of this bed of sand is about 35 feet above the river at low water.

Remnants of modified drift form frequent terraces in the Minnesota valley from New Ulm to its mouth. Their extent and hight in Carver and Scott counties have been noted on a preceding page, in speaking of the topographic features of this great valley. These deposits are gravel, sand and clay, horizontally stratified. In general, the mode of their deposition was like that of recent alluvium upon the bottomland or present flood-plain of the river. High water, like that which now prevails during a few days in the freshets of spring, was then maintained through the entire summer; and this was repeated yearly till the glacial sheet had retreated beyond the lines of water-shed of the Minnesota basin. The abundant supply of sediment through this time gradually lifted these floods upon the surface of thick and wide plains, which slope down the valley one to two feet per mile. After the departure of the ice, the supply of both water and sediment was so diminished that the river could no longer overspread these flood-plains and add to their depth, but has been occupied mainly in slow excavation and removal of these deposits, leaving remnants of them as high plains or terraces upon the sides of its valley. Often the sand and gravel of these terraces, though in nearly level beds, show an oblique stratification, and this usually dips in these counties northeastward, coinciding in direction with the current of the ancient floods and of the modern river.

Beven's creek has cut a channel in section 3, San Francisco, fully 100 feet deep in this valley drift, which consists of sand and gravel in thick beds, the upper 20 feet being fine, clayey sand. The coarsest layers of gravel contain fragments of stone up to one foot in diameter; and a boulder of granite four feet long was seen embedded in this bank about fifty feet below the top. Nearly all of its pebbles and fragments are granite, syenite, gneiss, and crystalline schists.

Origin of the brick clay. The beds of clay in this valley drift, which are used for brick-making at Jordan and Carver, show a very interesting kind of stratification. In Mr. Charles Rodell's excavation at Jordan, this clay is bedded in distinct horizontal layers from three to eight inches thick, averaging six inches. These layers are dark bluish, often finely laminated, changing above and below to a nearly black, more unctuous and finer clay, which forms the partings between them. These divisions are clearly seen through the whole extent of this excavation, which reaches 25 feet below the top of the clay and is four rods long. The hight of its top is estimated to be 65 feet above the river. The excavation of Nye & Co. at Carver, where the exposure is four rods long and 15 feet high, with about the same elevation above the Minnesota river as the foregoing, exhibits the same stratification, except that here the layers all have a nearly uniform thickness of three inches. There is a tendency to split at the darker partings, which are seen to extend continuously, never passing one into another, and preserving a very constant width of three inches apart, through the whole of the section exposed. They are from an eighth to three-quarters of an inch thick, gradually merging above and below into the less dark clay that makes up the principal mass of these layers. The bedding is nearly level, but dips 1° to 2° away at each side. In this depth of 15 feet there are thus about sixty layers, all closely alike. The alternating conditions which produced them were evidently repeated sixty times in uninterrupted succession. The only explanation for this which seems possible is that these divisions mark so many years occupied by the deposition of this clay. It appears that these clay-beds are of limited extent. The broad flood-plain was mainly built up by additions of fine gravel and sand spread over its surface by floods like those which now occasionally overflow the bottomlands. Clay could settle only where hollows were formed by inequalities in this deposition and left outside the path of the principal current. Now nearly all the features of the modified drift, as the general absence of shells or other fossils, its hillocks and ridges called kames, and its occurrence only in glaciated regions or in valleys of drainage from them, indicate that this formation was accumulated by streams discharged from a melting ice-sheet. If the origin of the modified drift that filled the lower part of the Minnesota valley was from such glacial melting, it is apparent that the floods would be greater and would bring and deposit more sediment in summer than in winter. Layers nearly like those in the clay at Carver and Jordan are also seen in other clay-beds in this valley and in that of the Mississippi in this state. The principal mass of each layer is regarded as the deposition during the warm portion of a year, and the very dark partings as the sediment during winter when the melting was less and the water consequently less turbid. At the excavation of Nye & Co., a few light gray or almost white laminæ were seen in the thicker and less dark part of these layers, their thickness being from a hundredth to an eighth of an inch. The upper part of these beds of clay are generally colored yellow to a depth varying from one or two to ten feet, the lower portion being blue. The limit of the yellow color in the clay at Jordan runs obliquely, being nearly parallel with the sloping surface, so that the same horizontal layers are partly blue and partly yellow, which shows that this is a discoloration by weathering.

At Chaska the clay used for brick-making is modified drift of interglacial age. It varies from 20 to 40 feet in thickness, being underlain by sand and covered by till from two to six feet thick, holding boulders of all sizes up to five or six feet in diameter, many of which are planed and striated. This till forms the surface, 30 to 35 feet above the river. The only fossils found here were fresh-water clam shells, which occurred in considerable numbers upon a space four rods in diameter near the middle of Gregg & Griswold's excavation, lying in the upper foot of the clay, just beneath the till. Details of several very interesting sections in these deposits are given on a following page, in connection with notes on the manufacture of bricks. In brief, this interglacial clay, overspread by till, testifies that an ice-sheet covered this region after the Minnesota valley had been eroded nearly as it now is.

"*Kettle holes.*" Another observation which seems to give the same testimony, and to show that the modified drift forming high terraces and plains in this valley was deposited during the recession of the ice-sheet, is presented in the notably uneven surface of the broad part of the terrace of this valley drift in Carver county between Carver and Beven's creeks. On this tract, composed, below the soil, of stratified gravel and sand, extending about two miles in width and elevated 125 feet above the river, are frequent depressions from 10 to 30 rods in diameter and 15 to 40 feet in depth below the general level, often inclosed without outlet, and some of them containing lakelets and sloughs. Such hollows have not been seen elsewhere in my explorations of these terraces along the Minnesota valley, which instead have generally a smoothly level contour. Their origin must apparently be referred to sedimentation while masses of ice occupied the places of these bowl-like depressions. Elsewhere the absence of such inequalities in the surface of the valley drift, as also the very rare occurrence of boulders in it, and the fact that no portion of it, excepting that just mentioned at Chaska, is known to be interglacial by having become covered with till, together show that the deposition of these beds of modified drift took place outside the limits of the retreating ice-sheet. The valley appears to have remained from excavation in an interglacial epoch, and to have become rapidly filled with sediments as soon as the ice by which it had been enveloped was melted away.

Depth of the alluvium at Belle Plaine. Alluvial beds fill the Minnesota valley at Belle Plaine, as shown by the section of the salt-well, to a depth about 150 feet below the present river at its stage of low water. This well, situated on the bottomland at nearly the same hight with the depot, or approximately 35 feet above the river and 730 feet above the sea, is reported by Prof. Alexander Winchell to have passed through the following succession of deposits: Soil and gravel, 9 feet; clay and gravel, 9 feet; sand and gravel, 18 feet; quicksand, 54 feet, having its base 90 feet below the surface; coarse sand, 1 foot; clay, 6 feet, in which was found, two feet from its top, a piece of grape-vine with bark; sand, 38 feet, varying from quicksand to coarse sand, in which, at 114 feet below the surface, inflowing water, under pressure from the bottom, filled the pipe twelve feet with sand, and a second time, at 125 feet, filled it five feet; then, gravel, quicksand, and coarse sand, 45 feet, having its base 180 feet below the surface, yielding water at 144 feet, which filled the pipe 10 feet, and containing another piece of grape-vine at 168 feet; next, from 180 to 200 feet, blue clay, 7 feet, and rock fragments, 13 feet, probably both boulder-clay or till; and, lastly, gravel, 2 feet; the whole depth of alluvium and drift being thus 202 feet, extending about 170 feet below the river. The next 8 feet are described as "shelly rock," the term being apparently used as by quarrymen, to designate the thinly bedded or loose, and partly disintegrated rock covering hard and compact stone, which was reached, according to this report, at 210 feet from the surface. Another description of this well, by Mr. P. M. Barker, who superintended the work, states that the thickness of alluvium and drift penetrated was 216 feet. The lower part of its section reaching in Potsdam sandstone and metamorphic rocks to a total depth of 710 feet, has been presented on a preceding page.

At the railroad bridge which crosses the Minnesota river close to its mouth, borings were made to a depth of 60 feet below the river-level without reaching the bed-rock. In the deep well at Mankato, drift was found to extend 65 feet below the river.

The ancient Minnesota river. This channel, excavated in the Lower Magnesian and Potsdam formations far below the bottom of the present valley, appears, as shown in the report of Blue Earth county, to have been eroded by a river during the later Paleozoic and earlier Mesozoic ages, before the Cretaceous subsidence which carried much of this state, with a large area farther west, beneath the sea. In the early part of the glacial period, when an ice-sheet covered all Minnesota, except its southeast corner, and reached south into southern Illinois and Missouri, a thick drift-sheet, mostly unmodified, was spread over all this region, probably covering most of this preglacial valley with an unbroken, moderately undulating expanse of till. During the ensuing interglacial epoch, the drainage of this area cut a channel, which, because of the natural slopes of the basin determined by preglacial erosion, coincides along much of its lower part, where it crosses the nearly horizontal Paleozoic formations, from Blue Earth and Nicollet counties to its mouth, with the old valley eroded in these strata long before the ice age. The preglacial, and probably also the interglacial river lay far below the present stream. The till of the later glacial epoch appears to have only partially blocked up this river-course along the greater part of its extent, and portions which may have been obstructed were soon channeled anew, and this valley from its mouth to New Ulm or beyond was filled with modified drift, to the hight of its present terraces during the recession of the last ice-sheet. After the departure of the ice from the Minnesota basin, this avenue of drainage continued through a long time to be the outlet of lake Agassiz, whence it received an immense volume of water, supplied from the melting ice-fields of northwestern Minnesota and of a vast region reaching far to the north and northwest over the basin of lake Winnipeg and the Saskatchewan river. As long as streams poured into this valley directly from the melting ice-sheet, its modified drift, gathered from the ice in which it had been held, continued to increase in depth; but when the great glacier had retreated beyond the limits of the basin of the Minnesota river, the water discharged here from lake Agassiz brought no modified drift, and was consequently a most efficient eroding agent. By this mighty river the valley drift so recently deposited was mostly swept away, and the channel was excavated to a depth lower than the present river and perhaps quite to the bottom of the sand in this valley at Belle Plaine, which is 150 feet below the river there and nearly 140 feet below low water in the Mississippi at Saint Paul.

Since the ice-barrier which had caused lake Agassiz disappeared and that lake was drained northeastward to Hudson bay, the Minnesota valley and that of the Mississippi below, carrying only a small fraction of their former volume of water, have become considerably filled by the alluvial gravel, sand, clay and silt, which have been brought in by tributaries, being spread for the most part somewhat evenly along these valleys by their floods. The changes produced by this postglacial sedimentation have been pointed out and ably discussed by Gen. G. K. Warren, who thus added much to our knowledge of the geological history of the Minnesota and Mississippi rivers. Lake Traverse and Big Stone and Lac qui Parle occupy hollows in the outlet of lake Agassiz due to inequalities of these recent deposits. At the mouth of the Minnesota river, the Mississippi has brought more sediment than its branch, which is thus dammed for a distance of thirty miles, to Little Rapids, with a depth of 20 to 25 feet at low water. The current of this part of the Minnesota through the dry season is very sluggish or imperceptible, and its surface often becomes considerably covered with the green scum of cryptogamous vegetation characteristic of pools and lakes. The channel here is from fifteen to twenty-five rods wide, with no lake-like expansions; but lakes from one to four or five miles long, and from a quarter to a half mile wide, lie near the river and parallel with it at each side, upon the bottomland. Lake Pepin, having a depth of about 60 feet, according to Gen. Warren, lies in the continuation of this valley which was deeply channeled by the outflow from lake Agassiz, because it has become unequally filled below the foot of this lake by the deposition of alluvium from the Chippewa river. Two of the tributaries of the Mississippi from the east were similar outlets of floods supplied by glacial melting after they had become free from their modified drift by flowing through a lake. Lake Superior, held by an ice-barrier on the northeast at a level about 500 feet above its present hight, overflowed at the head of the Bois Brulé river, by Upper St. Croix lake and the St. Croix river. The Mississippi valley at the mouth of this river has become more filled by postglacial deposits than its tributary, which is thus held as back-water twenty miles, to the head of lake Saint Croix, which is 25 feet deep. Lake Michigan, till the receding ice-sheet was melted from its present outlet at the north, similarly discharged southward by the Illinois river, which, like the foregoing, is obstructed at its mouth by the alluvium of the Mississippi. At low water the greater part of its length is dammed, and has a very slight and often imperceptible current through the two hundred miles from La Salle by lake Peoria to its mouth. Major Long remarked: "This part of the river may with much propriety be denominated an extended pool of stagnant water." All these results of recent fluvial action show that the drainage from the final melting of the ice-sheet excavated these valleys to depths much lower than they have now, and make it very probable that the deposits penetrated by the first 180 feet of the Belle Plaine salt-well are wholly postglacial.

The exposure of rock over which the Minnesota river flows at Little Rapids, ten miles below Belle Plaine, do not forbid this conclusion, for the topography of the valley in that vicinity indicate that a much deeper channel than that now occupied by the river may have existed there since the ice age, passing a mile and a half east and a mile northeast of the Little Rapids. This course of the river along which it is believed to have cut a channel corresponding to the depth that it had at Belle Plaine, extends northeastward diagonally across section 5, Sand Creek; then northerly through the west part of section 33, Louisville; and thence northwesterly through section 29. It thus leaves the present river a mile south of these rapids, and returns again to it about a mile south of Carver, after passing east and north of the island-like sandstone outcrops of section 32, Louisville. The recent accumulation of sediments that fill this avenue to a hight slightly above the Little Rapids, has turned the river that way, so that it has abandoned its former course and now flows over ledges of sandstone.

Wells in Carver county. Examples of the sections of the drift found by well-digging in Carver county are as follows:

Watertown. Frank Acker; in the village: well, 60 feet deep; soil, 2 feet; yellow till, 28; yellow and blue till, in alternating layers, 6 feet; blue till, 24; from sand at the bottom water rose fifteen feet. W. B. McClellan, who has had much experience at making wells in this and adjoining townships, reports that such interblending of the yellow and blue colors of the till is frequent. He states that the bluish lower till is more compact and harder to dig with a spade, but that it is preferable for boring, because it holds together better and clogs the auger less than the upper yellowish till. Mr. McClellan has found fragments of lignite, the largest eight inches long, in nearly every one of some two hundred wells dug or bored by him in this region; but no shells nor other fossils have been detected. The wells of Watertown average 20 to 30 feet in depth, finding the yellowish till 10 to 25 feet thick, and entering blue till below. Often the water seeps from this boulder-clay; but water-beariug veins or layers of sand or gravel, from one or two inches to three feet in thickness, occur in many of these wells.

James H. Patrick; sec. 7: well, 32 feet; soil, 2 feet; yellowish till, 28 feet, inclosing, about midway in it, a bed of water-bearing gravel, one to two feet thick; and, at the bottom, blue till, which was dug into only 2 feet.

Hollywood. Leopold Jopp; sec. 16: well, 58 feet; yellowish till, 20; dark bluish till, 38; water rose from sand at the bottom sixteen feet in five minutes.

Camden. Peter Smith; N. W. ¼ of sec. 28: well, 16 feet; soil, 2; yellow till, 10; harder blue till, 4; water comes slowly at the junction of these colors in the till,

Waconia. Wells at the village are 25 to 50 feet deep, in till.

Benedict Meiser; in the village: well, 28 feet; soil, 2; yellowish till all the way below to quicksand at 28 feet, from which water rose two feet. At Mr. Meiser's blacksmith shop the well, 23 feet deep, is likewise yellowish till to gravel at the bottom, from which water rose eight feet.

Pastor Friedrich; in the village: well, 40 feet; soil, 2; yellow till, 20; very hard blue till, 18; water was struck in gravel at the bottom, from which it rose twenty feet.

Charles Siltz; sec. 23: well, 68 feet; soil, 2; yellow till, 20; blue till, 46; water came in slowly at the depth of about fifty feet.

Gottlieb Schoewe; sec. 31: well, 52 feet; yellowish till, 30 feet; abruptly changed, as usual, to the dark bluish, very hard, lower till, which reaches 22 feet and lower; water comes slowly in a thin sandy vein at the junction of these tills, but no such sandy streaks, nor any water, were found in the lower till.

Laketown. Frederick M. Goldsmith, in the northeast corner of this township, has a well 145 feet deep, which passed through yellow and blue till, and into a considerable depth of sand below, but the exact thicknesses of these deposits were not learned. Water stands where it was found, about 140 feet below the surface.

N. L. Swenson; sec. 8: well, 44 feet; soil, 2; yellowish till, 33; dark blue till, 5 feet; and whitish sand, 4 feet, and reaching lower. Gas of disagreeable smell rushed with a roaring sound from this sand as soon as it was struck, and for about twenty minutes following. Afterward it continued so that men could only remain in the well a half hour at a time. In the lower two feet dug in this sand, water of excellent quality was found running through it with a current from northwest to southeast. Several pieces of lignite were found in this well at various depths below the first fifteen feet.

George B. Nilson; sec. 10: well, 30 feet; yellowish or reddish till, 26 feet; dark bluish, much harder till, 4 feet; water came slowly at the junction of these colors in the till.

William Friedrich; sec. 32: well, 22 feet; yellow till, 21; gravel, with water, 1 foot.

Dahlgren. Andrew Larson; sec. 23: well, 70 feet; soil, 2; sand and gravel, 30; fine sand, 15 feet; yellow and blue clay, stony, interstratified, 8 feet; gravel, with water, 10 feet; hard, blue till, 5 feet, and extending lower; water stands fifty-five feet below the surface.

Charles Skone; sec. 25: well, 136 feet deep; soil, 2 feet; sand and fine gravel, 20 feet; yellowish clay and quicksand, interstratified, 6 feet; dark, somewhat stony clay, 1 foot; quicksand, with water, about three feet; blue gravelly clay, till, with two or three boulders at its top, but containing few large stones, very hard, about 100 feet; same, but softer and more sandy, 4 feet and reaching lower; water fills this well to thirty feet below the surface, coming slowly in the quicksand at that depth, but none was found in the till below.

The well at East Union post-office, in the S. W. ¼ of sec. 35, is 35 feet deep, being all the way gravel and sand. The three wells last described are on the Minnesota valley terrace of modified drift.

Benton. Horace Russell; N. W. ¼, sec. 7: well, 20 feet; all yellowish till.

Baltes Bitzer; sec. 9: well, 24 feet; soil, 4 feet; yellow till, 10 feet; very hard, dark bluish till, 5 feet; gravel, 6 inches, with a little water; dark till, as before, 4½ feet, and reaching below.

Robert Müeller; S. W. ¼, sec 12: well, 30 feet, all yellowish till; water comes up at 26 feet.

Young America. In Young America village, the well at Julius Martin's store, 30 feet deep, was soil, 2 feet; yellow till, 6 feet; light gray till, 4 feet; and harder blue till, 18 feet. Water seeps at 12 feet and again at 20 feet below the surface, and stands fifteen feet deep. Other wells in this village are 20 to 40 feet deep.

In Norwood village, three wells, representing the mean and the two extremes in depths, are as follows: 1. At K. Thompson's house; well, 24 feet; yellow till, 20 feet; dark bluish till, 4 feet and lower; with water seeping from the lower part of the upper till. 2. At K. Thompson's blacksmith shop; well, 13 feet; yellowish till, 8 feet; harder, blue till, 5 feet; water seeps at their junction. 3. Fred Drews; well, 75 feet; soil, 2; yellow till, 6; much harder blue till, 67, and continuing below; no good supply of water obtained, but this well becomes filled in a wet time from the upper till.

Henry Grimm; sec. 1: well, 20 feet; all yellowish till; to water, in sandy vein at bottom, rising three feet.

Hancock. James F. Rendle; sec. 12: well, 30 feet; yellow till, spaded, 12 feet; harder blue till, picked, 18; water seeps from the upper till. At his barn, some 200 feet farther south, another well, also 30 feet deep, is yellow till, 10; and blue till, 20; with a spring of water at the bottom, from which it rises two or three feet. Fragments of lignite were found in each of these wells.

Patrick Duffee; S. E. ¼ of sec. 13: wells were dug here at two places unsuccessfully, going 20 to 30 feet deeper, through compact blue till, than this well, only a few rods distant, in which water was finally found, all being on about the same hight of land. The section of this third well was soil, 2 feet; yellow till, 33 feet, including occasional layers of blue till near the bottom, not exceeding a foot in thickness;

water, struck in quicksand at 35 feet, rose immediately seven feet, and continued so that within one day it attained its permanent level, with a depth of about twenty-five feet.

San Francisco. James Dougherty; sec. 19: well, 70 feet; soil, 2; yellow till, 30; dark bluish till, less strong than the preceding, 25 feet; yellow sand and gravel, the latter sometimes consisting of pebbles alone, with no sand, interstratified with layers of bluish "hardpan," 13 feet; good water in abundance is found near the bottom of this well, but does not rise. Many fragments of lignite were found in the last thirteen feet, and a few also in the till above.

Wells in Scott county.

Louisville. Blasius Beisang; at Marystown, in the southwest corner of sec. 36: well, 30 feet; soil, 2; yellow till, 12; harder, blue till, 16; water seeps scantily from the lower part of the upper till. Two wells, situated within about a mile at the east and at the west from Marystown, are 75 and 100 feet deep, in till.

Eagle Creek. August Bise; S. W. ¼ of sec. 29: well, 60 feet; soil, 2; yellow and gray till, hard, all picked, 58 feet and lower; water seeps from a sandy streak at 45 feet from the surface, filling the well two or three feet, and probably running out at a dry sandy seam three feet above the bottom.

Glendale. Jeremiah Frawley; S. W. ¼ of sec. 18: well, 40 feet; soil, 2; yellow clay, 16; sand and gravel, coarsest below, 22; water, about eight feet in depth.

Francis McNamara; sec. 29: well, 40; soil, 2; yellow and light gray till, mostly picked, 38 feet; no water.

Credit River. Bridget Donlon; N. E. ¼ of sec. 22: well, 34 feet; soil, 2; sand, 10; blue till, 22; water comes mostly from the lower part of the sand; some seeps also from the till.

Spring Lake. Simon Roach; S. W. ¼ of sec. 13: well, 48 feet; soil, 2; yellow till, 20; harder, blue till, 26; water rose from the bottom eighteen feet in five minutes, and remains there permanently.

Sand Creek. Gerhard Koch; sec. 21: well, 22 feet; soil, 2; yellow till, 10; blue till, 9; sand, 1 foot; not much water.

John B. Geiger; sec. 22: well, 60 feet; soil, 2; yellow till, 25; blue till, harder, 32; sand, 1 foot, and deeper; from which water rose slowly during two or three days, attaining a depth of twenty-five feet.

T. M. Pitmon; southwest corner of sec. 19: well, 72 feet; soil, 2 feet; sand and gravel, 60 feet, with a very plentiful supply of water in its lowest foot; stratified blue clay, 10 feet, and extending lower, having its top nearly on the same level with that of the clay used at Mr. Rodell's brick-yard. This well and the next are on Spirit hill, a terrace of modified drift west of Jordan.

St. Lawrence. Thomas O. Holmes; N. E. ¼ of sec. 25: well, 81 feet; soil, 2 feet; all sand and gravel below, with abundance of water, two or three feet deep at the bottom. It will be noticed that this well, though deeper than the last, which is near it, found no clay.

Blakely. H. C. Hespenheide; sec. 21: well, 98 feet; dug 30 feet in yellow and blue till, and bored 68 feet lower, in dark bluish till. While this work was going forward at 98 feet, water burst into the well from the side forty feet above the bottom, and filled the well rapidly to twenty-seven feet below the surface, remaining permanently at this level.

W. R. Salisbury; south part of section 30: well 48 feet; soil, 2 feet; yellow till, 13 feet; blue till, 30 feet; and "mud, like a lake bottom," 3 feet, containing many small gasteropod and bivalve shells of recent species, like those common in ponds and sloughs, besides grass and apparently grains of wild rice. From the last stratum, water of disagreeable smell and taste rises in this well eight or ten feet. The locality is just at the top of the bluff of the Minnesota valley, so that the entire depth of the drift here, composed almost wholly of till, is known to be more than three times that of the well.

Belle Plaine. Town well, in the village: 93 feet deep; soil, 2; hard clay, 3; sand and fine gravel, 33; yellowish gray, partly reddish till, all picked, 55 feet; to sand from which water rose eight feet.

John Fitzsimmons; in the southwest part of the village: well, 92 feet; soil, 2; fine, yellow sand, 48; coarse gravel, 2 feet; yellowish gray clay, probably till, 20; dark bluish till, 20; water comes from sandy streaks eight feet above the bottom.

William H. Weibeler; well, 126 feet, deepest in the village: soil, 2; sand and fine gravel, 48; yellow till, 16 feet; dark bluish till, 60; from sand and coarse gravel at the bottom, water rose six feet.

Thomas Terry; sec. 24, at the west side of the township: well, 25 feet; soil, 2; yellow till, picked, 10; sand, 2; blue till, harder than the upper till, 11 feet, and lower. Water, coming from the sand, stands six or seven feet deep in the dry season.

Helena. Henry Ehmo; sec. 16: well, 21 feet; soil 2 feet; yellow till, spaded, but hard, 14 feet; sand

and fine gravel, 6 inches; blue till, picked, harder than the upper till, 4 feet; sand and gravel, 1 foot, and more, from which water rose eight feet in a half day.

Railroad well at New Prague; in the south edge of sec. 34: 73 feet deep, soil and yellow till, about 10 feet; blue till, 60; quicksand, 3 feet; water issues in large supply at the bottom, but becomes only three to five feet deep.

Cedar Lake. James Corcoran; sec. 14: well, 30 feet; soil, 2; yellow till, picked, 10; gravel, 1 foot; blue till, softer, spaded, 16; yellow sand, 1 foot, and reaching lower, from which water rose four feet.

John Hoeorka; sec. 33: well, 32 feet; soil, 2; yellow till, 24; alternately blue and yellow till, 6; water seeps.

New Market. Peter Wagner; sec 20: well, 22 feet; soil, 2; yellow till, 4; blue till, 16; water seeps, scanty.

Frank Mahoweld; sec. 29: well, 33 feet; black soil, 3 feet; yellow till, picked, 10 feet; slightly softer blue till, 20 feet, and below; water seeps, scanty.

MATERIAL RESOURCES.

The productiveness of the soil in this district, its abundance of timber, and its favorable climate, have been noticed on a preceding page.

Water-powers. The utilized water-powers of Carver county are as follows:

Beven's Creek mill: sec. 2, San Francisco; head, fourteen feet; canal, about a half mile long; one run of stone by water; two more to be added by steam-engine.

Dahlgren mill; Philip Siegel: on Carver creek, in sec. 24, Dahlgren, one and a half mile west of Carver; head, fifteen feet.

Union flour mill: at Watertown, on the South fork of Crow river; head, seven feet.

Water-powers used in Scott county are:

J. G. Mock's mill: on Sand creek, sec. 4, Helena; head, eleven feet.

Foss, Wells & Co.'s mill: on Sand creek at Jordan; head, twenty-three feet.

Jordan City mills. F. Nicolin: also on Sand creek at Jordan; head, twenty-four feet; eight run of stone; ten crushers; uses water-power during about five months, and steam the remainder of the year, when water is low.

Jackson mill; Frank Baumhoefer: S. W. ¼ of sec. 13, Jackson; mill-pond is filled from adjacent springs; head, thirty-five feet.

S. W. Pond's mill: near the Minnesota river, in the northeast part of Eagle Creek, 1¼ miles east of Shakopee; head, ten feet; from springs a quarter to a half mile distant, whence nearly as much water flows in the drought of summer as at the wet season.

Eagle Creek mill; J. W. Humphrey's: in south edge of sec. 7, Glendale; head, twenty feet; on Eagle creek, which is formed by springs within one to two miles distant, having water enough for one set of millstones every hour in the year, but much more in rainy than in dry weather.

Michael Allen's mill: in the N. W. ¼ of sec 17, Glendale; near the last, and similarly supplied from springs; head, sixteen feet.

Hamilton mills; Quinn Brothers: on Credit river at Hamilton; head, twelve feet.

All these are grist and flouring mills.

Building stone. Quarries in the limestone at St. Lawrence are owned by Abraham Bisson and Philip Corbel, both renting to others the privilege to quarry for 50 cents a cord. The stone is sold at $3 or $3.50 per cord, the first of these quarries supplying fifty cords yearly and the second about twenty cords yearly. Mr. Bisson's quarry has been worked about twenty years. Its area is some 150 by 100 feet, with a depth of 5 to 7 feet.

The Jordan sandstone is quarried at Jordan by Frank Nicolin and Philip Kipp. It lies in beds from eight inches to two or three feet thick. Mr, Nicolin's flour-mill at this place, built of this stone, is 60 by 70 feet in area and 75 feet high, in six stories, having its walls five feet thick at the base and twenty inches at the top. Besides this structure, which was erected in 1878 and 1879, Mr. Nicolin's quarry has supplied $2,000 worth of stone, sold to the Minneapolis & St. Louis railway for bridge masonry and to other purchasers. Mr. Kipp's quarry, opened in 1879, supplied during that year about $200 worth, at $3.75 per cord. Foss, Wells & Co. also quarried this stone to build their mill and elevator.

The limestone at Shakopee, excepting a layer about two feet thick, more sandy than the rest, is too much seamed and fractured and too irregularly bedded for use as a building stone. In Louisville, Mrs. M. A. Spencer owns a quarry of this limestone which has been worked fifteen years, with annual sales from $200 to $950. The stone is in layers from one to three feet thick, hard and compact, except that small cavities sometimes occur in it. It has been used for much of the bridge masonry of Scott and Carver counties, including the railroad-bridges at Chaska and Carver.

The boulders of the drift, though seldom plentiful, may be commonly gathered in sufficient amount for the masonry needed by farmers, in foundations, and walls of cellars and wells.

Lime. Both quarrying and lime-burning in this district are confined to Scott county, because rock-outcrops, except in the vicinity of Little Rapids, occur only on that side of the river.

The Shakopee limestone gives a very 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. At Shakopee, J. B. Conter burns 15,000 barrels yearly, selling it at Saint Paul and Minneapolis for 55 cents per barrel of 200 pounds. The upper 6 to 8 feet of the section here, above the calcareous sandstone used for building, produce leather-colored lime; while the 12 feet below these beds yield a very dark, blackish lime. The kiln, a continual-burner, is operated during about eight months of the year. Lime has been manufactured here ever since the first settlement of the town in 1852. The area of the quarry is 240 by 220 feet, and its depth 15 to 20 feet. The sales of stone for building purposes are perhaps a hundred cords yearly, at about $2 per cord.

Mr. Conter also burns about 15,000 barrels of lime yearly at the quarry and kilns before mentioned, five miles to the southwest, in Louisville. This limestone and the lime produced are nearly the same as at Shakopee. It is arenacous, but the quarry shows no continuous layer of sandstone. Lime-burning has been carried on here about fifteen years.

In New Market, Peter Fisher and John Tempel burn white lime from boulders, selling it at $1.50 per barrel.

Two kilns of lime were burned from the Shakopee limestone at Hamilton in 1858, when the mill now owned by Quinn Brothers was being built.

Bricks. At Shakopee, Schroeder Brothers have made bricks six years; annual product, 700,000, selling at $5 per thousand. The recent alluvial clay of the Minnesota river is used with admixture of one part of sand to two of clay. These bricks are red, and of good quality.

At Chaska four companies were engaged in this business at the time of the survey of this county, in 1879, all upon an area about an eighth of a mile in extent. The clay deposit probably occupies an area not more than a quarter of a mile in diameter. It is yet practically inexhaustible. This locality is close north of the Hastings & Dakota railroad, at the east edge of the village, about a half mile west of the railroad bridge. It is a part of the till-covered terrace on which the village is built, about 35 feet above low water of the Minnesota river. Brick-making was begun here about fifteen years ago, and has been steadily increasing to the present time. In 1879 and the years next following, six to ten millions of bricks, cream-colored, of the most durable quality, were made here annually. The first yard worked has been owned by Gregg & Griswold ten years. Their yearly product is from two and a half to three millions, selling at $5 to $6 per thousand. They also make faced brick, at $8 to $10 per thousand. From forty to fifty men are employed for six months. Sand is mixed in varying proportions according to the quality of the clay, the average being about one part in ten. This company have machinery and room to make forty thousand bricks daily.

The section at Gregg & Griswold's excavation, 250 feet in length from northwest to southeast, 150 feet wide, and 25 feet deep, has 3 to 5 feet of very coarse till at the top, yellow (except the one or two feet of black soil next to the surface), showing imperfect stratification in a few places, but mostly unmodified, and containing numerous boulders, some of which are glaciated, of all sizes up to six feet in diameter. Next below, in the southeast part of this pit, but not in its northwest part, is stratified yellow sand, 1 to 6 feet thick. These deposits are underlain by yellowish clay, about 10 feet thick, its upper portion for two to four feet being rejected because more or less filled with calcareous concretions, a half to one inch thick, while its lower part, from which these are absent, makes good bricks. This clay, colored by the oxidation and hydration of its iron through the action of infiltrating water, is irregularly stratified and much contorted, and holds pockets of sand, one to five feet in diameter. Its lower line is irregular, undulating three to four feet in slopes of 45°, and is in some places partly interstratified with the underlying dark bluish clay, which is excavated 10 to 15 feet vertically, and reaches at least 15 feet more below this pit, not being penetrated at that depth. This dark clay is very compact; it is laminated, but not conspicuously; and nearly all of it is quite irregularly contorted and folded. It rarely contains vertical seams of yellow clayey sand, extending down three feet from the overlying bed, and also small pockets of the same yellow sand, a foot in diameter, apparently isolated at one or two feet below the top of this blue clay. It also includes sandy masses of the same dark color as itself, varying from two to ten feet in diameter, concentric or indistinct in their lamination, apparently entirely surrounded by clay, with definite separating lines. These beds, below the stratum of till at the surface, in this and all the excavations here described, are free from all gravel and boulders, except that perhaps a half dozen fragments of rock, varying in size up to six inches or a foot in diameter, are found in the clay-digging of a whole summer.

When this pit was first opened, in the central part of its present area, many bivalve shells were found over a space four rods or more in diameter, occurring some five feet below the surface, under the till, which had boulders here up to five or six feet in diameter, lying in the upper foot of the yellow clay, or in some thin bed between that and the till. These shells were three to four inches long, "such as are found in rivers and lakes of this region." They were the only fossils that have been found in these pits, which have yielded no pieces of either wood or lignite.

L. Warner's excavation, opened some ten years ago, from which he made about two millions of bricks yearly, employing thirty men through six months, is six rods south of the foregoing, and shows nearly the same section of clay overlain by till. This pit is twelve rods in diameter, nearly circular, and 25 to 30 feet deep, so that its bottom is but little above the river. The yellow clay, about 10 feet thick, is mixed with sand for tempering in the respective proportions of three and one; while the underlying dark blue clay, because it includes sandy layers, needs only an addition of one-sixth as much sand as clay. The junction of the yellow and blue clays is very irregular, with some interstratification, and both are much contorted. Pockets of yellow sand, 4 to 5 feet in diameter, concentrically laminated, occur in the upper clay, from which they are indistinguishable in color. The blue clay, into which this excavation goes 10 to 12 feet, and whose base was not reached by a boring 15 feet deeper, is preferred for brick-making.

Wiest & Kruse's excavation, opened about twelve years ago, from which they make from one and a half to three millions of bricks yearly, employing twenty to forty men, is some thirty rods northwest from these, having nearly the same area as the last and a depth of 20 feet. The section of this pit and of a well here, in descending order, is as follows: very coarse gravel, mostly showing distinct stratification, partly ferruginous, holding numerous boulders up to five feet in length, 4 or 5 feet; yellow, clayey, fine sand, 3 to 6 feet; dark blue clay, 20 feet; similarly dark blue quicksand, not containing much water, 8 feet and extending below. The upper 10 to 15 feet of the clay has been dug for the manufacture of bricks. It has few or no limy concretions. A small proportion of sand is mixed with it for tempering, more being required by the lower than by the upper part of this clay. It is finely laminated, and has occasional whitish laminæ, such as have been already mentioned in the clay of Nye & Co.'s excavation in Carver; but no such layers with dark partings as were described there, are seen in this or either of the preceding clay-pits. The stratification of this clay is very irregularly contorted, twisted, broken, and rolled up, but as a whole is approximately horizontal. Two concentrically laminated masses of dark gray sand, three and five feet in diameter, were seen embedded in this clay, with their tops about three feet below its upper line. The overlying clayey sand has a regular and nearly horizontal stratification; and at the west side of the pit is filled with vertical, cylindric, irony concretions, one to one and a half inches in diameter and two to three feet or more in length.

Schlafle, Strobach & Streissguth began brick-making here in 1876, and made 900 thousand in 1878; they expected to make three millions in 1879, employing forty men. Their excavation, situated about an eighth of a mile south of the last, was 100 feet in diameter and 20 feet deep. Sand is mixed with the clay to temper it, in the respective proportions of one and five, approximately, somewhat more being needed by the lower than the upper part of the clay. The section here is till, 3 to 6 feet deep, covering the surface, black in its upper one to two feet which are soil, and yellowish below, unstratified, inclosing many stones and boulders of all sizes up to five feet in diameter, a considerable part of them glaciated and rarely retaining striæ; underlain by yellowish sand, 5 to 12 feet thick, which has mostly a very confusedly contorted, folded, and involved stratification, inclosing many masses, flakes, shreds, and sheets of yellowish clay, bounded by definite but exceedingly irregular outlines; succeeded below by dark bluish clay, 10 to 25 feet thick, under which is sand. This clay at the south end of the pit is only 10 feet thick, and within four rods farther south it thins out to nothing, while at the north end of the pit its thickness is 25 feet. Its lower line where it lies on the sand beneath descends at this place about 30 feet in a distance of 150 feet from south to north.

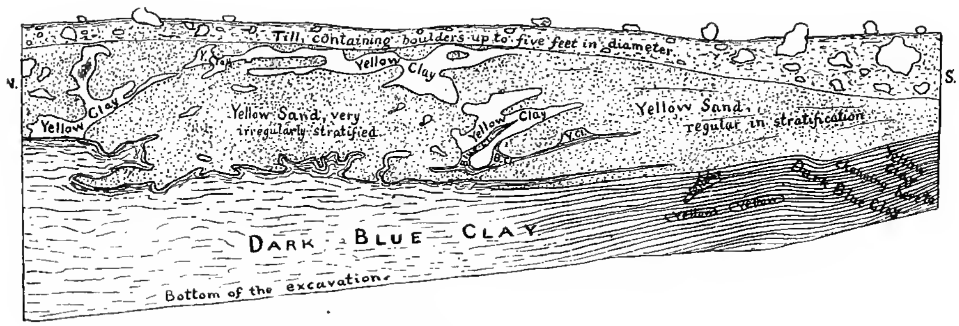


FIG. 12. SECTION IN DRIFT, CHASKA.

Scale, 15 feet to an inch.

Fig. 12 shows the east side of this excavation as it was exposed at the time of my visit. The masses of clay inclosed in the sand have evidently been torn from the underlying clay, their difference in color having been since produced by weathering. Indeed, some of the lower patches of clay in the sand retain their dark bluish color. The disturbing force, which is believed to have been the foot of a vast ice-sheet, seems to have moved from north to south, and possibly terminated near this place; for the south parts of both the clay and sand here show a more regular and undisturbed stratification than any other of the beds underlying the till in these pits. Excepting Wiest & Kruse's pit, where the very coarse gravel and boulders at the surface and the sand next below are modified drift laid down by a stream when this ice-sheet was being melted away, their upper deposit is unmodified glacial drift, directly underlain by the crumpled stratified beds over which this ice advanced, strangely contorting them, rolling up the strata of clay, and here and there leaving them with cavities, which, through the agency of currents of water, soon became filled with sand.

In the section here figured the northern part of the clay has been much plowed up and torn into pieces, but its southern part has a smooth upper line and an unbroken stratification, which, however, is somewhat contorted at one place, apparently by lateral pressure from the north. This south part is also very interesting because it exhibits peculiar layers in the clay, separated by darker partings, like those that have been before described as observed in the brick-clay of Carver and Jordan. Here these layers are one to three inches thick at the south and gradually increase in thickness northerly, becoming three to five inches thick within three rods, near the middle of this section, and disappearing in its northern part, where the clay is massive and only obscurely laminated. The partings are more unctuous than the rest of the layers, and vary from an eighth to half an inch in thickness, gradually changing above and below into the less dark clay, which, as at Nye & Co.'s excavation in Carver, contains occasional thin laminæ that are light gray. The clay splits readily at these dark partings. Such resemblances seem to prove this clay to be of the same age with that of Carver and Jordan, respectively two and eight miles farther south, where it forms a portion of the valley drift, undisturbed in stratification, and not associated with deposits of till. It appears thus that the last ice-sheet, after it had so far retired from this region that mollusks lived in the river-bed or sloughs of this valley, re-advanced, its border being again pushed southward as far as to Chaska.

Other important observations were supplied here, respecting the alteration from a dark bluish to a yellowish color. The top of the clay rises nearest to the surface at the south end of this section, and has there undergone this weathering to a depth of several feet. The layers into which the yellow color is thus extended are gradually changed, as they continue northward, in a space one to two feet wide, to a dark bluish color. Within one rod farther north, a tongue-like projection of the yellow, definitely bounded, reaches three feet downward from the top of the clay across its dark layers; and, contiguous to this, one or two of its layers, five feet below its top and inclosed in the dark bluish clay, are changed to a yellow color along an extent of fully ten feet. The base of this clay deposit, in its south part, has similarly had its iron oxidized and hydrated by water which has permeated it several inches from the sand below. The limy concretions, which occur more or less in the upper one to three feet of the clay in all these excavations, are also plainly a result of weathering.

Since the date of these observations, the business of brick-making at Chaska has much increased. In 1884 eight brick-yards were in operation here, employing in the aggregate three hundred and fifty men, consuming in that year about 18,000 cords of wood, and producing 30,000,000 bricks. These yards are all supplied with brick-making machinery. The greater part of their product is used for building in St. Paul and Minneapolis, but large shipments are also made to more distant points in this and adjoining states. The ownership of the several yards in 1884, and statistics of their business, were stated in the *Minneapolis Tribune* as follows:

"Andrew Rudele employs forty-eight men, consumes 2,000 cords of wood, and turns out 4,000,000 brick this season.

Burline & Sons employ sixty-five men, consume 3,000 cords of wood and will produce this season 6,000,000 brick.

Henning & Melwin employ thirty-five men, and use 1,500 cords of wood, with a product of 3,000,000 brick.

Baker & Streissguth employ thirty-five men, and use 1,500 cords of wood, their operations covering 3,000,000 brick.

Gregg & Griswold have forty men, burn 1,500 cords of wood, and will fill contracts to the extent of 3,000,000.

Strobach, Grenier & Co. operate two yards, employ ninety men, consume 6,000 cords of wood, and will turn out 8,000,000 brick this season.

Andrew Wiest employs thirty-five men, and will produce this season about 3,000,000."

At Carver the bank from which J. M. Nye & Co. obtain their clay for brick-making, situated in the west part of the village, has its base 50 feet and its top 110 feet, approximately, above the river. The section, in descending order, is fine, light yellow sand, 20 feet; gravel, with interstratified sand, very coarse in its upper layer, which holds rock-fragments up to one and two feet in diameter, 24 feet; clay, yellowish in its upper one to one and a half feet, and dark bluish for 15 feet of vertical exposure, forming the lower part of this section, below which it is said to extend 15 feet more, having a total thickness of 30 feet. The top of this clay varies in hight, and two rods east of the excavation, from which this description was taken, it rises ten feet higher. The peculiar stratification exhibited here and at Jordan has been described and discussed in a preceding part of this chapter. Brick-making was begun here about eight years ago. The annual product is from 300 to 500 thousand, sold at $5 to $6 per thousand. These bricks are cream-colored and of excellent quality. Sand is used to temper this clay in the proportion of one of the former to two or three of the latter.

About two-thirds of a mile southwest from Carver, Andrew Ahlin has two yards, his product of bricks, like the last in color and quality, being from one to one and a half millions yearly. The oldest of these yards has been worked ten years. Its clay requires no sand for tempering. The section is yellow sand and gravel at the top, 15 feet; clay, yellow for its upper one or two feet, and below dark bluish, with a total thickness of 35 feet, the upper

20 feet of which is employed for brick-making, the lower part not being used because it would require some intermixture of sand; underlain by fine, white sand, which is known to extend 15 feet. The hight of this bed of clay is estimated to be from 70 to 105 feet above the river. Mr. Ahlin's second yard, opened in 1879, is some forty rods northeast from the foregoing. It at first worked a slide of clay, lying about 40 feet above the river; but the adjoining bank to the hight of a hundred feet is found by borings to be clay, yellow for 5 or 10 feet near the surface and dark blue below.

At Jordan the excavation whence Charles Rodell takes clay for brick-making is in the base of the terrace of modified drift called Spirit hill. The section, in descending order, is gravel, 10 to 25 feet, containing pebbles up to six inches in diameter; clay, 40 feet, yellowish in its upper 4 to 10 feet and dark bluish below, exposed and worked to a depth from its top of about 25 feet; lying upon very hard dark blue till. The top of this clay is about 65 feet above the Minnesota river. Its stratification and weathering have been before noticed. Mr. Rodell has made bricks here fifteen years, averaging about 500,000 yearly, and selling at $6 per thousand. For tempering, one part of sand is mixed with three of clay. The bricks are cream-colored and of very durable quality. In burning they first change to light red, then to cream-color, and near the fire attain a yellowish tint. He also makes fire-bricks, of the same size as ordinary bricks, which he sells at $8 per thousand. The demand for them, however, is small, being only four to eight thousand yearly, through the last six or eight years. The clay employed is dug about ten rods southwest from this excavation, at the top of the bank, where the section is soil, 2 feet; sandy clay, used for fire-bricks, 3 to 5 feet; and sand and gravel below.

At Belle Plaine, about an eighth of a mile east of the depot, Jacob Kranz has made red bricks twelve years; annual product, 300,000, selling at $5 to $6 per thousand. The clay used is recent alluvium of the river, with which he mixes one-sixth as much sand as clay.

Springs. The remarkable springs which supply the water-powers of several mills in northern Scott county, have been already mentioned. One of these, on the west branch of Eagle creek, near the west line of section 18, Glendale, is said to be intermittent, alternately flowing a few minutes and then stopping for an equal or longer time. It seems probable that Prior lake, which has no visible outlet, flows underground to some of these springs in sections 17 and 18, Glendale. At its northeast extremity a narrow strait leads into a little lakelet, called Pocket lake, having an area of about two acres. At times of low water in Prior lake, which is said to vary six feet in its hight, a current runs from it into Pocket lake; and it is reported that once the water was so low as to divide them, when Pocket lake became nearly drained, being made several feet lower than Prior lake.

Numerous large springs issue from the bluffs of Beven's creek, and one of these, in the northeast quarter of section 3, San Francisco, on the south side of this stream, about a fourth of a mile west of the mill, has formed large masses of the very porous travertine commonly called "petrified moss." These and most of the springs that flow from the lower part of the bluffs of the Minnesota and its tributaries, like the wells of this region, are excellent water for drinking and cooking, but are too "hard" with the soluble carbonates of lime and magnesia to be well adapted for use in washing with soap. Very rarely springs or wells are found, which have a slightly bitterish or alkaline taste because they hold sulphates in solution; and springs of this kind, issuing from the foot of the bluff near the river at Belle Plaine, led to exploration for brine in the underlying strata by the deep well, the section of which has been already noted.

Salt. This substance is not present in noteworthy amount in the water of either the springs or the deep well at Belle Plaine. Both the Professors Winchell concurred in the opinion that, in the rocks here penetrated, "there is almost a certainty that no salt would be obtained, and that no lower formation would offer better inducement to sink the well deeper." Professor S. F. Peckham, in the winter of 1873 and 1874, made an incomplete chemical examination of the water from the neighboring springs, which had first attracted attention, carrying the work far enough, as he reports,* "to show that it contains only a small proportion of chlorides of any kind, and also to justify the statement that the brine belongs to the class of 'bitter brines,' containing more sulphates than chlorides, and a larger proportion of alkaline earths (lime and magnesia) than alkalies (soda and potash). I have found nothing as yet, in my examination of this mineral water to justify the expectation that it can be made of any commercial value as a source of common salt." In reporting a later partial analysis, made in 1877, of water from these springs, Prof. Peckham calls it "nothing but a hard well or spring water," and states his results as follows:†

"Mineral matter in solution,	25.10 grains to gallon.
Organic and volatile matter in solution,	5.37 grains to gallon.
Total solid matter in solution,	30.47 grains to gallon.
Chlorine,	3.152 grains to gallon.
Silica,	1.465 grains to gallon.
Ferric, aluminic, and phosphoric oxide,	.068 grains to gallon.
Barium sulphate,	a trace.
Sulphuric oxide,	1.033 grains to gallon.
Lime,	5.896 grains to gallon.
Magnesia,	.544 grains to gallon.

Alkalies and carbonic oxide were not determined."

ABORIGINAL EARTHWORKS.

In section 17, Blakely, on Mr. Ellis' farm, is an artificial mound, three feet in hight, of the usual circular, dome-like form. It is on the upland, about 225 feet above the Minnesota river, which is a half mile distant to the northwest. This mound was opened several years ago, and a vessel of rudely ornamented earthen ware was found in it.

About a dozen such mounds occur in the southeast quarter of section 20, Louisville, on land of Mrs. M. A. Spencer, lying within a quarter of a mile to the east and south of her house. They are scattered upon uneven land, and vary from two to four feet in hight.

There are three aboriginal mounds in the public square at Chaska, each four or five feet high and about twenty-five feet across. Several others, that formerly existed near there, have been destroyed in grading streets and house lots.

Thirty artificial mounds, varying from one to four feet in hight, lie on the verge of the plateau of modified drift opposite Chaska, close east and southeast of the railroad bridge, and about 125 feet above the river. They extend along a distance of some fifty or sixty rods, in a course that is nearly straight but bends slightly to follow the margin of the bluff. Most of them are situated within three rods from this margin, but a few are from ten to fifteen rods from it.

One and a quarter miles east of Shakopee, and close south of Mr. Pond's mill, are three mounds, each about six feet high and forty or fifty feet in diameter. They are about 35 feet above the river. From the most western of these east-southeast to the most eastern is approximately four hundred feet. The southwest part of the latter lies on boulders three to five feet in size. Several other mounds, from three to six feet high, occur within a half mile eastward.

At Hamilton an aboriginal mound, about two feet high, lies three rods southwest of the schoolhouse; and another, one and a half feet in hight, was seen a quarter of a mile farther south, on the west side of the road.

* Second annual report, p. 87.

† Sixth annual report, p. 127.

CHAPTER V.

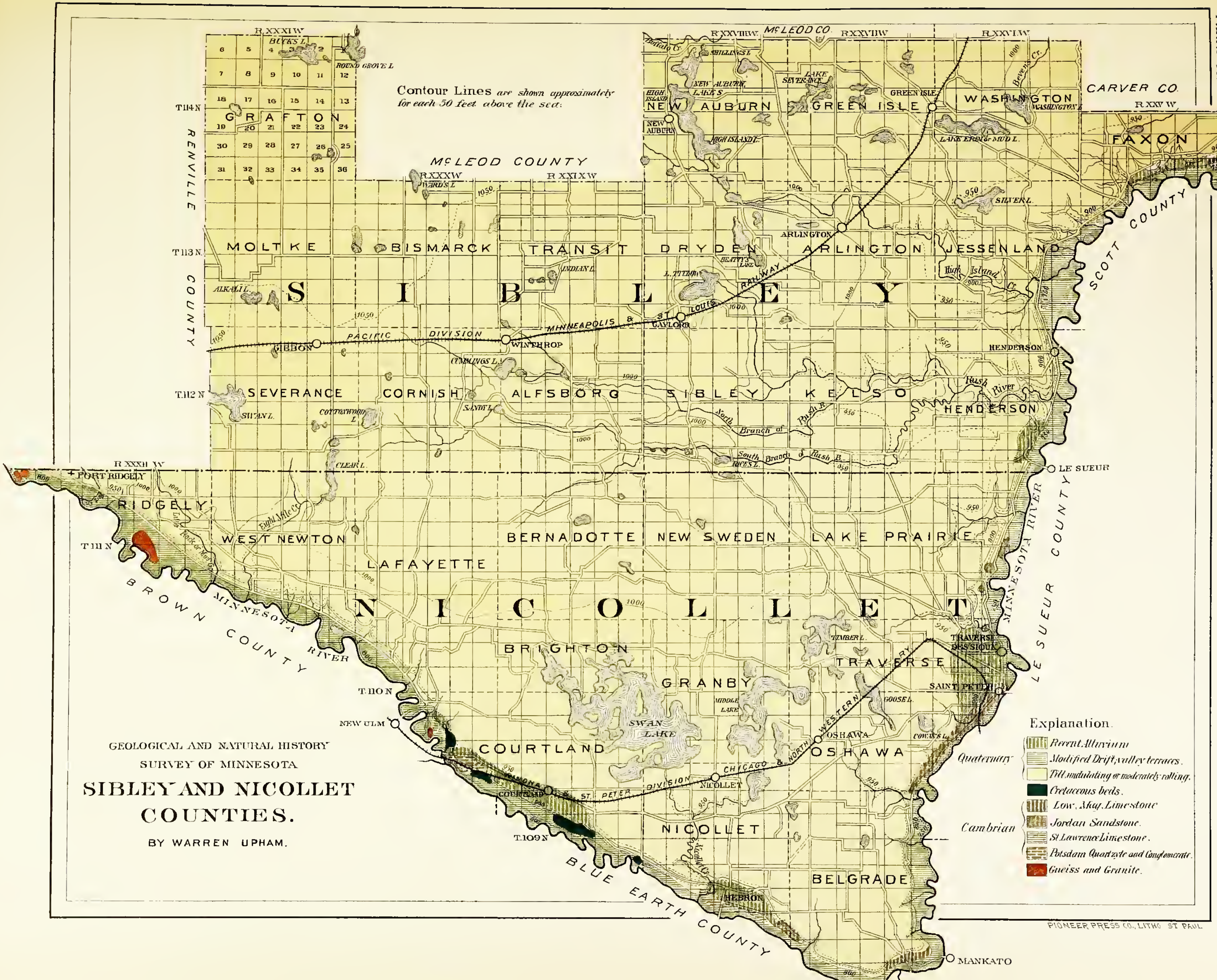
THE GEOLOGY OF SIBLEY AND NICOLLET COUNTIES.

By WARREN UPHAM.

Situation and area. Sibley and Nicollet counties (plate 36) are in the central part of the south half of Minnesota, lying in the angle formed by the great bend of the Minnesota river at Mankato, which above this bend is the south boundary of Nicollet county, and below forms the east boundary of both these counties. Henderson, the county-seat of Sibley county, and Saint Peter, that of Nicollet county, are situated at their east side on the Minnesota river, Henderson being distant about 50 miles, and Saint Peter about 65 miles, southwest from Saint Paul and Minneapolis. Other towns and villages are New Auburn, situated at the west side of New Auburn or High Island lake, in the north part of Sibley county; Traverse des Sioux, in Nicollet county, two miles north of Saint Peter, and Oshawa, Nicollet, and Courtland, situated west of Saint Peter in the same county, on the Winona & Saint Peter division of the Chicago & Northwestern railway.

The extreme length of Sibley county is 42 miles, extending from east to west. Its width is principally 18 miles, but in part of its west half this is reduced to 12 miles. This county includes fourteen entire townships of the governmental surveys, each of which, six miles square, has been organized as a civil township, and portions of four other townships of the original surveys, which form three civil townships, Faxon, Jessenland and Henderson, adjoining the Minnesota river, each having an area less than six miles square. The area of Sibley county is 597.73 square miles, or 382,545.75 acres, of which 19,737.61 acres are covered by water.

Nicollet county has the form, approximately, of an isosceles triangle, its two longer sides, on the north and on the southwest, being nearly equal, in length about 42 miles, and its eastern side or base being 22 miles. It includes seven


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
SIBLEY AND NICOLLET
COUNTIES.
BY WARREN UPHAM.
Contour Lines are shown approximately for each 50 feet above the sea.
Explanation.
Quaternary
Recent Alluvium.
Modified Drift, valley terraces.
Till, undulating or moderately rolling.
Cretaceous beds.
Cambrian
Low. Mag. Limestone.
Jordan Sandstone.
St. Lawrence Limestone.
Potsdam Quartzyte and Conglomerate.
Gneiss and Granite.
SIBLEY
NICOLLET
McLEOD COUNTY
McLEOD CO.
CARVER CO.
SCOTT COUNTY
LE SUEUR COUNTY
BLUE EARTH COUNTY
BROWN COUNTY
RENVILLE COUNTY
MINNESOTA RIVER
GRAFTON
NEW AUBURN
GREEN ISLE
WASHINGTON
FAXON
MOLTKE
BISMARCK
TRANSIT
DRYDEN
ARLINGTON
JESSENLAND
SEVERANCE
CORNISH
ALFSBORG
SIBLEY
KELSO
HENDERSON
RIDGELY
WEST NEWTON
LAFAYETTE
BERNADOTTE
NEW SWEDEN
LAKE PRAIRIE
BRIGHTON
GRANBY
TRAVERSE
COURTLAND
OSHAWA
NICOLLET
BELGRADE
GIBBON
WINTHROP
GAYLORD
ARLINGTON
HENDERSON
LE SUEUR
TRAVERSE DES SIOUX
SAINT PETER
MANKATO
NEW ULM
FORT RIDGELY
HEBRON
SWAN LAKE
MINNEAPOLIS & ST. LOUIS RAILWAY
PACIFIC DIVISION
CHICAGO & NORTH WESTERN RY.
WINONA & ST. PETER DIVISION
T.114 N
T.113 N
T.112 N
T.111 N
T.110 N
T.109 N
R.XXXI W.
R.XXX W.
R.XXIX W.
R.XXVIII W.
R.XXVII W.
R.XXVI W.
R.XXV W.
R.XXXII W.
PIONEER PRESS CO., LITHO. ST. PAUL

entire townships of the governmental surveys, and fractions, large or small, of fourteen others. The civil organization comprises the city of Saint Peter and thirteen townships, of which only two, New Sweden and Bernadotte, have exactly an extent six miles square. The area of Nicollet county is 464.61 square miles, or 297,351.78 acres, of which 18,469.37 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Excepting a small tract in the north edge of Sibley county, through which Buffalo creek, a tributary of the South branch of Crow river, flows, these counties lie within the basin of the Minnesota river, to which their drainage takes place by numerous small streams. Beven's creek, rising in Washington lake, flows northeasterly into Carver county, which it crosses in an easterly course to the Minnesota. High Island creek, having its source in the lake of this name at New Auburn, flows in an east-southeast course about sixteen miles and enters the Minnesota river at the middle of the east side of Jessenland. Next to the south is Rush river, which has its mouth six miles farther south, at the middle of the east side of Henderson, two miles south of the town. This stream is formed by the union, five miles above its mouth, of two branches, which receive their farthest waters from Cornish, 25 or 30 miles west of the Minnesota, and thence flow eastward through the southern tier of townships of Sibley county, nearly parallel with each other and only from one to three miles apart.

In eastern Nicollet county the Minnesota receives three small creeks, each about four miles long, and several others which are only one to two miles long but are never dry, because fed by perennial springs. Similar short but unfailing brooks issue also in many places from the ravines or *cooleys* that intersect the bluff of the Minnesota valley at the southwest side of this county. Four streams of more considerable size are also tributary to the Minnesota river upon that side, namely, Nicollet creek, about six miles long, the outlet of Swan lake; Eight Mile creek, also about six miles long, the outlet of Clear lake; Little Rock or Mud creek, which rises in southeastern Renville county and flows about twelve miles south and southeast, entering the Minnesota nearly three miles east of the outcrops of gneiss in sections 15 and 22, Ridgely, which were formerly called Little Rock; and Fort creek, about six miles long, which also flows from southeastern Renville county into Nicollet county, passing close east of Fort Ridgely.

Both these counties contain throughout their extent frequent lakes, varying in size from a few acres to hundreds, or in a few instances thousands, of acres. High Island lake, at New Auburn, so named for an island of drift which rises from it to a hight of 20 or 30 feet, is the largest in Sibley county, its length being about four miles, with a south-southeast trend, and its width from a quarter of a mile to one mile. Shillings lake, a short distance north from the north end of the preceding, has an area of about one square mile. Other lakes worthy of mention in Sibley county are Washington lake, at the center of the township of this name; lake Erin, or Mud lake, three miles long from east to west, and from a quarter to half of a mile wide, in the west part of this township; lake Severance, two miles long from northeast to southwest, in the west part of Green Isle; Silver lake, two miles long from east to west, in the north part of Jessenland; Tilton lake, of similar extent with the last, in the south part of Dryden; Indian lake, a half mile in diameter, near the center of Transit; Round Grove lake, at the northeast corner of Grafton, and an unnamed lake two miles farther west, each exceeding a mile in length; Alkali lake, nearly a mile long, in the south part of Moltke; Swan lake, about two miles long from east to west, in the west part of Severance, and Clear lake, of similar length, but trending from north to south, in the southeast part of this township, and extending into Nicollet county; Cottonwood lake, in section 19, Cornish; Cummings lake, about a mile long, and Sandy lake, of half this size, crossed by the line between Cornish and Alfsborg; and Rice's lake, about a mile long from east to west, through which the South branch of Rush river flows in sections 33 and 34, Sibley.

Swan lake, in the central part of Nicollet county, has an area of about fourteen square miles, and is the largest lake in the district here reported. It is quite irregular in outlines, with numerous projecting points, bays, and islands. Its greatest extent, which is from northwest to southeast, is about eight miles, and the diameter of its broad portion is three miles. Middle lake, also very irregular in form, is situated less than a mile east of Swan lake, and extends about four miles from north to south. Within a mile northeast from the northeastern extremity of Middle lake is Timber lake, of similarly irregular shape, reaching about two miles from north to south and an equal distance from east to west, named for the tract of timber which stretches from it two or three miles eastward. Among the smaller lakes of this county are Goose and Cowan's lakes, situated southeast of Timber lake and within a few miles west of Saint Peter; Horseshoe lake, in the northwest edge of Belgrade; and an unnamed lake, about a mile long, lying mostly in sections 2 and 11, Nicollet.

Some of the lakes are shallow throughout, though of considerable extent, and are filled with aquatic grasses, rushes, and white and yellow pond lilies. Examples of this kind are lake Erin in Washington Lake township, and Indian lake in Transit. Others, as Washington lake and Round Grove lake, are sheets of very clear water.

Topography. Sibley and Nicollet counties are part of the nearly flat, but slightly undulating, expanse, consisting of glacial drift at the surface and to a depth varying from 100 to 200 feet or more, extending 150 miles from northwest to southeast, with about half as great width, through the central part of which the Minnesota river flows from Big Stone lake to Mankato. The chief topographic feature of this area is the deep channel or valley in which the Minnesota river lies, which was excavated during the ice age by a much larger river than that of the present time. To that ancient river which was the outlet of lake Agassiz, the glacial lake that occupied the basin of the Red river and lake Winnipeg, the name *River Warren* has been given, in honor of Gen. G. K. Warren, who was the first to publish an adequate description of this remarkable valley. On the south and east sides of the district here described, this valley is from one to two miles wide, and from 175 to 225 feet deep, this descent from the gently undulating expanse on each side being made by steep bluffs, at the foot of which are the bottomland, often a mile wide, and the Minnesota river. The hights of the bluffs, composed of till, or unmodified glacial drift, inclosing layers of gravel and sand in some places, and frequently having rock in their lower part, are as follows: at Fort Ridgely and New Ulm, 175 to 180 feet above the river; at Mankato, 200 to 225; at Saint Peter and Ottawa, 220 to 230; and at Le Sueur, Henderson and northward, 210 to 225. Further description of this valley, and notes respecting its outcrops of the rocks underlying the drift, its terraces of till and especially of modified drift, and its more recent alluvial bottomland, are presented in later portions of this chapter.

Excepting the Minnesota valley and the comparatively small valleys of its tributaries, the area of these counties has a nearly uniform surface, diversified only by gentle undulations which rise by prolonged slopes in smooth swells 10 to 20, or rarely 30 feet above the depressions, some of which are occupied by sloughs, or marshes, and lakes. In any extensive view upon the prairie, the surface to the horizon on all sides is seen to be approximately level. It has, however, a very slight descent eastward, averaging about one foot per mile, and thus amounting in the length of these counties to about 40 feet. The number of *sloughs* (so called upon the prairie, but usually denominated *marshes* in the wooded area) is greater than that of the lakes, and they average of smaller size, varying from a few rods to a mile or more in extent.

The tributaries of the Minnesota river in these counties are small, but they have cut channels of considerable depth, because the main valley has given them the requisite slope. Fort creek, close east of Fort Ridgely, has a valley 75 to 100 feet deep, and this diminishes, in following up the stream, to 30 or 40 feet at five miles from the Minnesota valley. Similar excavation has been accomplished in the last two or three miles of the other little streams which enter the Minnesota river from Nicollet county. The valleys of the north and south branches of Rush river in Kelso and of High Island creek in Arlington, are about 30 feet deep and from twenty to fifty rods wide, but their size is greater toward the Minnesota river, and less toward their sources.

These and larger streams which enter the Minnesota valley seldom have deposited any great amount of sediment at their mouths, showing that their work in excavation was mostly done at the same time with the erosion of the main valley. On the contrary the frequent short ravines which have been cut in the bluffs of this valley by rills and springs, many of which flow only after rains, are more recent in their origin, and the material that filled their place is commonly spread in fan-shaped, moderately sloping banks below their mouths which are thus kept at a hight from 30 to 40 feet above the present flood-plain. The road from Fort Ridgely to New Ulm runs along the bluff on the north side of the river at the only hight where a nearly level straight course could be obtained, being just above these deposits and below the ravines.

Elevations, Pacific division, Minneapolis & Saint Louis railway, in Sibley county.

From profiles in the office of Robert Angst, engineer, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
Line of Carver and Sibley counties, grade,	45.0	995
Green Isle,	48.1	999
Arlington creek, water, 968; grade,	53.7	984
Arlington,	54.3	995
Rush river, outlet of lake Titlow, water, 981; grade,	59.7	986
Gaylord,	62.3	993
Winthrop,	69.3	1016
Rush river, water, 1023; grade,	73.5	1030
Gibbon,	77.4	1046
Line of Sibley and Renville counties, grade,	82.2	1046

Elevations, Winona & Saint Peter division, Chicago & Northwestern railway, in Nicollet county.

From John E Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Minnesota river bridge,	135.00	791
Minnesota river, low and high water,	135.00	733–756
Saint Peter,	136.19	812
Oshawa,	146.29	982
Nicollet,	150.88	980
Courtland,	158.56	936
Minnesota river bridge,	162.50	821
Minnesota river, high water,	162.50	807

The elevation of the Minnesota river along the boundary of Nicollet and Sibley counties, in which distance it descends 100 feet, has been determined by the United States engineer corps, under the direction of Gen. G. K. Warren, and more recently of Capt. C. J. Allen. The hights here given from these surveys denote the ordinary stage of low water in the river.

Minnesota river.

	Feet above the sea.
At the west extremity of Nicollet county,	796
At Fort Ridgely,	793
At New Ulm,	784
At the mouth of the Cottonwood river,	782
[High water of Cottonwood river, by railroad survey, 807.]	
At Judson,	760
At the mouth of the Blue Earth river,	756
At Mankato, low and high water,	752–778
At the Winona & St. Peter railroad bridge,	733
[High water here, by railroad survey, 756.]	

At Saint Peter,	730
At Traverse des Sioux,	726
At Ottawa,	723
At Le Sueur,	717
[High water here, by railroad survey, 740.]	
At East Henderson,	711
At Henderson,	710
At Faxon,	700
At Belle Plaine,	696
[High water here, by railroad survey, 725.]	

The lowest portion of each of these counties is the bottomland bordering the Minnesota river. The highest land in Sibley county is in Grafton, its most northwest township, which is from 1,050 to 1,075 feet above the sea, or about 150 feet above the general level of the east part of this county adjoining the Minnesota valley, and 375 feet above the Minnesota river where it leaves the county. The highest land in Nicollet county, lying in its northern part, is about 1,025 feet above the sea, being some 50 feet higher than the average of the belt adjoining the valley of the Minnesota river, and 300 feet above this river and its bottomland at the line between Nicollet and Sibley counties.

The average hights of the townships of Sibley county are estimated as follows: Faxon, 900 feet above the sea; Washington Lake, 975; Jessenland, 910; Henderson, 915; Green Isle, 1,020; Arlington, 980; Kelso, 960; New Auburn, 1,025; Dryden, 1,020; Sibley, 1,000; Transit, 1,025; Alfsborg, 1,010; Bismarck, 1,040; Cornish, 1,020; Grafton, 1,060; Moltke, 1,040; and Severance, 1,025. The mean elevation of Sibley county, derived from these figures, is approximately 1,000 feet above the sea.

The following are estimates of the average hights of the townships of Nicollet county: Lake Prairie, 950 feet above the sea; Traverse, Oshawa and Belgrade, each 950; New Sweden, 1,000; Granby, 980; Nicollet, 960; Bernadotte, 1,010; Brighton, 980; Courtland, 940; Lafayette, 990; West Newton, 975; and Ridgely, 950. The mean hight of Nicollet county above sea-level, derived from these figures, is approximately 970 feet.

Soil and timber. A fertile soil, black to a depth of one and a half to two feet, overspreads the whole of Sibley and Nicollet counties. No contrast is noticeable in respect to the depth and productiveness of the soil of the prairie and of the timbered tracts, when compared with each other. Nearly the whole of this district is adapted for cultivation, and yields abundant returns to the farmer. The only exceptions, besides the steep bluffs bordering rivers and creeks, are the occasional sloughs or marshes, which are yet valuable for their heavy grass and supply a large part of the entire hay crop. With ample rain-fall quite uniformly distributed through the successive seasons of the year, so that serious damage because of either drought or excessive rains is rarely known, and with generally clear and invigorating air, this district is unsurpassed in its healthfulness and desirability for agriculture. At present, wheat, pork and beef, and dairy products, are its chief exports; but all the grains, vegetables and small fruits usually cultivated in this latitude are also successfully grown here. When nearer markets and increased demand are created by the growth of large manufacturing towns throughout the state, doubtless a much greater variety of farm and garden products will be raised for sale, permitting a rotation of crops and requiring more careful cultivation, yielding at the same time proportionally greater profits, and thus leading to the subdivision of most of the large farms.

Timber covers the northeastern third of Sibley county, being the west edge of the area called the Big Woods. Its southwest limit is at New Auburn and Arlington, and in the northwest and southwest portions of Henderson. On the north branch of Rush river it reaches west to the middle of Kelso township. Farther westward this county is prairie and has only small groves beside lakes and a scanty margin of timber here and there on the streams. The traveler across this area may often look away as far as the eye can see, without including either bush or tree of natural growth within the view; but frequent cultivated groves are seen, set out around dwellings to screen them from the force of winds.

Nicollet county has considerable timber within the Minnesota valley and on a narrow belt of the adjoining upland, especially in its east part (which includes the outskirts of the Big Woods), and as far west as Nicollet creek. A tract of woodland three miles long and two miles wide extends east from Timber lake, and smaller groves border Swan and Middle lakes. Mostly, however, this county is prairie, having shrubs and trees only beside lakes and water-courses.

The species of wood found in this district include the white and red elms, bass, sugar and soft or silver maples, box-elder, black, bur and white oaks, butternut, bitternut hickory, white and black ash, ironwood, wild plum, black cherry, American crab-apple, Juneberry, common poplar or aspen, large-toothed poplar, cottonwood (beside rivers and lakes), water beach, willows, hackberry, paper or canoe birch, and rarely, in bleak situations, as on lake shores or river bluffs, the red cedar.

Along the Minnesota river timber occurs in a nearly continuous though often very narrow strip, generally leaving much of the bottomland treeless. From Courtland northwestward the bluffs on the northeast side of the river have for the most part only thin and scanty groves or scattered trees. The southwestern bluffs, on the contrary, are heavily wooded through Blue Earth and Brown counties, excepting two or three miles at New Ulm. They also are frequently well timbered in Redwood and Yellow Medicine counties; but in Lac qui Parle county they are mostly treeless, and have only occasional groves. The greater abundance of timber on the southwestern bluffs appears to be due to their being less exposed to the sun, and therefore more moist, than the bluffs at the opposite side of the valley.

The absence of trees and shrubs upon large areas, called prairies, in this and neighboring states, is generally attributed correctly to the effect of fires. Through many centuries fires have almost annually swept over these areas, generally destroying all seedling trees and shrubs, and sometimes extending the border of the prairie, by adding tracts from which the forest had been burned. Late in autumn and again in the spring the dead grass of the prairie burns very rapidly, so that formerly a fire within a few days sometimes spread fifty or a hundred miles. The groves that remain in the prairie region are usually in a more or less sheltered position, being on the border of lakes and streams and sometimes nearly surrounded by them; while areas that can not be reached by fires, as islands, are almost always wooded. If fires should fail to overrun the prairies in the future, it can hardly be doubted that nearly all of them would gradually and slowly be changed to forest. Yet it does not appear that fires in forests of the western states are more frequent or destructive than in the eastern states, and our inquiry must go back a step further to ask why fires east of the Appalachian mountains had nowhere exterminated the forest, while so extensive areas of prairies were due to them in the West. Among the conditions which have led to this difference, we must probably place first the generally greater amount of rain-fall in the eastern states.

GEOLOGICAL STRUCTURE.

Except within the valley of the Minnesota river, the bed-rocks of these counties are concealed by drift. In this valley outcrops of Eozoic or Archæan granite, gneiss and schist occur one and a half miles west of Fort Ridgely, and again four miles southeast from this fort; and small exposures of granite are found fifteen miles farther southeast, situated opposite the southeast part of New Ulm. Close east and northeast of the last mentioned ledges of granite, a low ridge of conglomerate appears, and between one and a half and three miles farther southeast is a conspicuous outcrop of red quartzyte, both of which are believed to belong to the Potsdam period, near the base of the Palæozoic system. The next higher rocks in ascending stratigraphic order that are seen in the Minnesota valley in these counties are the St. Lawrence limestone, exposed in the vicinity of Hebron in Nicollet county, and in Jessenland and Faxon, Sibley county; and the Jordan sandstone and Lower Magnesian limestone, which together form the lower part of the bluffs of this valley in many places at the east side of Nicollet county, and the south part of the terrace on which the city of Saint Peter is built. These formations constitute the middle portion of the Lower Magnesian series, which in the basin of the

Mississippi river is much better exposed and is described in other chapters. The only other bed-rocks found in this district are sandstone, conglomerate and shales, the last containing calcareous layers, seen in the Minnesota valley in Courtland, Nicollet county, which are referred to the Cretaceous series. These rocks are here described in their order of age, beginning with the oldest and ending with the newest.

Archæan rocks. On the bottomland of the Minnesota river, in the west extremity of Ridgely township, one and a half miles west of Fort Ridgely, are the ledges which supplied the stone used in building the fort. An excavation found near the north end of the outcrop, is in porphyritic granite, which contains abundant gray feldspar crystals, three-fourths to one and a half inches long and one-third to two-thirds as wide; it also contains occasional masses six to twelve inches long and half as wide, mostly made up of black mica in small grains. This ledge is also traversed by several flesh-colored felspathic veins, two to six inches wide. The other rock-exposures near by are mostly feldspathic granite, flesh-colored, not noticeably porphyritic. In one band here, the rock is hornblende schist and mica schist, much contorted, weathering to a very rough, honey-combed surface. This band extends several rods from north to south, and dips 45° to 60° W.

All these ledges have been considerably water-worn by the river flowing over them at some former time. They rise 15 to 25 feet above the river, a deserted channel of which, filled with water, adjoins them on their west side. After the time in which these rocks were water-worn, they have been faintly striated by an ice-sheet. The striæ mostly bear S. 60° E., but occasionally vary from this direction to S. 50° E. and S. 70° E., or ten degrees each side from the prevailing course.

Four miles below Fort Ridgely, Archæan ledges again appear, in the south part of section 15 and the northeast part of section 22, Ridgely. This outcrop, formerly known as Little Rock, a translation of the name given to it by the French voyageurs and traders, extends about one mile from northwest to southeast, forming numerous mounds and short ridges which rise 40 to 60 feet above the river, and are surrounded by bottomland and marshes 5 to 15 feet above the river. The rock is partly gneiss, much contorted and often obscure in its lamination, and partly granite, both being flesh-colored, apparently from weathering. In its gneissic portions very small rusty stains are often present, due to decomposition of minute crystals of iron pyrites. Nearly all these ledges are abundantly jointed and seamed. The dip is not clearly exhibited. Professor Winchell conjectured, from the outlines and slopes of surface, that it may be 35° or 40° to the north. No fall or rapid is produced here in the river, and the bottomland on its southwest side has very scanty exposures of this rock or none.

Professor Winchell describes the mineralogical character of this rock as follows:* "Its outward appearance is that of a reddish granite, made up of the ternary granite compound, the separate grains of which are not coarse, the largest ones being the feldspar. The quartz is milky, or often amethystine; the mica is rather scarce for typical granite, and the feldspar is red or flesh-colored. The red color greatly predominates, giving a reddish tinge to the whole stone, wherever the weathered surface is kept free from lichens, or where the interior is freshly exposed by cuts for quarrying. On close inspection of this granite with a pocket-glass, there seems to be much uncertainty about the color of the feldspar. The red color is most prevalent outside of the feldspar crystals, or only on their surfaces, as if the stain arose from rustiness and weathering, and had permeated the loosened granular mass by being in solution in water. There is a powdery, at least a gritty and sandy cement, which fills the interstices within the mass and between the grains of quartz and the crystals of feldspar, that seems to be generally redder than the distinct quartz or feldspar portions. Yet that loose and more finely pulverized part seems to be made up entirely of quartz, appearing, on close examination, to have the light color and distinct fracture of glassy quartz, the red color vanishing from sight. The color seems to be located very largely in the cement, as the red quartzyte at New Ulm, suggesting the query whether this may not be more highly metamorphic sandstone. In a deep fracture, however, the red color is much less observable, being replaced by a gray, the feldspar grains becoming more evident and the whole rock appearing much like the St. Cloud granite."

Thirteen miles of the valley next to the southeast have no rock exposures. Then two small outcrops of granite are found, lying in the bottomland in the S. W. ¼ of section 27, Courtland, opposite the southeast part of the city of New Ulm. The more southern of these outcrops is about a hundred feet square; ten rods north-northwest from this is a second ledge a few rods in extent. They rise 15 to 20 feet above the bottomland, or about 25 feet above the river. This granite is very coarse-grained. Its principal constituent is flesh-colored feldspar, which in some portions forms crystals an inch or more in length. Weathering has made this rock very friable on the surface, but the interior is firm and hard. It is traversed in several directions by joints; the most noticeable are nearly vertical and extend from north to south. This is the most southeastern exposure of the Archæan rocks in the Minnesota valley. It is about three hundred feet west from the south end of the conglomerate, and one and a half miles northwest from the quartzyte, which are next described.

Potsdam conglomerate and quartzyte. The outcrop of conglomerate, lying in the west half of section 27, Courtland, is about a thousand feet long, in which

* Second annual report, p 161.

distance its hight rises from 10 to about 60 feet above the river. Its strike or course is N. 20° E., while the dip, measured by Prof. Winchell, is 18° E. S. E. Its greatest exposure vertically at any one place is about 20 feet. The beds vary from one to six feet in thickness. It is a massive, tough, dark gray or reddish conglomerate. The pebbles in it are all more or less water-worn; they are generally abundant, often occurring nearly as thick as they could be packed. They are of all sizes up to a diameter of one foot or a little more. These pebbles are remarkable as consisting, almost without exception, of only two kinds of rock, which occur together in nearly equal abundance and dimensions. One of the two classes is apparently a jasper, usually a dull red and massive, but in many of the fragments laminated, or in thin bands, which are sometimes dark, sometimes yellow; the other class is white quartz, massive, now and then containing foreign particles, and occasionally smoky in color. The origin of this conglomerate may have been from the action of sea-waves upon a coast where only these two kinds of rocks were exposed. The only pebble found, which could not be referred to these classes, was a scrap of fine-grained gneiss, two inches long. Neither the granite that outcrops close at the west, nor the quartzyte that occurs upon a large area one and a half to three miles distant toward the southeast, seems to be represented.

The quartzyte outcrop lies wholly on the northeast side of the Minnesota river, beginning at the Redstone railroad bridge, and extending one and a half miles to the east and southeast. The highest knobs of its southern part rise 100 to 125 feet above the river, while its most northern part forms a nearly level tract of about equal hight, three-quarters of a mile long, lying at the south side of the carriage road. The greater part of this outcrop dips northerly. South of the west railroad-cut the dip is 27° N. 10° E. At another cut, a third of a mile east from this, it is 45° N. N. E. It frequently varies as much as ten degrees within a few rods, and its north portion seems to be nearly level in stratification. The thickness exposed in the whole outcrop may be 250 feet. The rock is a compact hard quartzyte, of red or reddish gray color. It is variously divided by joints, and its solid masses often have a tendency to break into rhomboidal fragments. The layers are from three to twelve inches thick, mostly without lamination at the north; but at the southwest, near the base of the strata here exposed to view, they show fine laminæ and are partly red shale, in layers one to four inches thick, softer than the rest of the rock.

A small exposure of very hard quartzyte, different from the rest of this rock in its color, which is bluish gray instead of red, is seen about 500 feet east from the railroad bridge and 300 feet west from the west rock-cut before mentioned. It is in the east part of a sand-cut of the railroad, and rises three feet above the track. At the northwest, the upper part of the quartzyte here seen is quite coarse-grained, and rarely incloses small pebbles, the largest being about an inch in diameter. So far as observed, they include only red jasper and white quartz, like those of the conglomerate just described. Stone suitable for cellar-walls and foundations is quarried from this outcrop.

Professor Winchell writes of the character and relationship of the rock here, as follows:* "The surface of these knobs, and in general the surface exposure of the whole, is much more indurated and quartzitic than those lower beds that have been opened by quarrying and by the cutting for the railroad grade. It appears as if the greatest metamorphism had taken place over the surface, the lowest strata seen being more perfectly bedded and thinner, as well as argillaceous and wave-marked. The whole is of a reddish color, varying from brick-red in the lower beds, to a dark red or purplish hue, in the highly metamorphosed portions. It sometimes shows a finely pebbly structure, and some small spots of a softer texture, which on fracture have some appearance of a greenish impure chert, or of a serpentinous or epidotic composition. These greenish spots are closely impacted in, or chemically united with the mass, as if derived from it. Other parts are more plainly a sandstone, much less glassy on fracture, showing all the characters of the *Potsdam sandstone*, as recognized in the Lake Superior district.

"The following characters indicate the *Potsdam* age of this outcrop of red quartzyte: 1. Its red color, spotted with lighter color, even to cream color. 2. Ripple-marks and mud-cracks. 3. Worm-marks and fucoids. 4. Thin laminæ of shale separating the beds. 5. The very observable and regular bedding. 6. The impossibility of setting any limit between the evidently sandy and sedimentary portions and the quartzitic and metamorphosed portions. They pass one into the other in the distance of twenty feet. 7. The highly inclined position of the strata. 8. Its *arenaceous* character, taken as a whole, in distinction from the talcose and slaty, or the hornblenic and the micaceous nature of the *Huronian*.

"In some of the thin bedding near the lowest part exposed, mica scales are visible on the planes of the bedding. When fresh they are black, but if weathered they are of a golden yellow color.

"In many places there are evidences of a higher stage of the Minnesota at some earlier time. These consist of furrows and water-worn surfaces. There are some pot-holes, worn usually so as to have their elongated dimension in the direction of the river, their shape being generally oval. One of the largest noticed was twenty inches long and fifteen inches wide. Its depth was twenty-four inches. These water-marks rise 120 or 125 feet above the river."

The coarse conglomerate in section 27, Courtland, probably lies somewhat lower, stratigraphically, than this quartzyte. Although the observations of dip in the quartzyte indicate that it may not be conformable with the conglomerate, it yet seems likely that they are associated strata, belonging to the same epoch. They appear, with the similar quartzyte outcrop farther southwest, in Cottonwood, Pipestone and Rock counties, and in southeastern Dakota, to be the southwestward continuation of the Keweenawan series in the region of lake Superior, which there consists of interstratified copper-bearing trappean rocks, conglomerates, and red sandstone and shale, much uplifted and eroded.

* First annual report, p. 76; and Second annual report, p. 158.

The time of their deposition we must refer to the earlier part of the Potsdam period, in the later part of which the nearly level red sandstone of the southern shore of lake Superior from the falls of St. Mary to Fond du Lac, and the red shales and sandstone of the artesian wells at Mankato, Minneapolis, Hastings, Red Wing and Lake City, were deposited, being supplied from the eroded Keweenawan formation.

St. Lawrence limestone. Eleven miles southeast from the quartzyte, we find at Hebron and Judson the first exposure of the Cambrian rocks within the Minnesota valley. Hence the further course of the valley upon the boundary of these counties has frequent outcrops of these rocks. The three members of the Cambrian series seen in the Minnesota valley, in their ascending stratigraphic order, are the St. Lawrence limestone, Jordan sandstone and the main body of the magnesian limestone.

The St. Lawrence limestone at Hebron extends from Nicollet creek, the outlet of Swan lake, about one and a half miles eastward. It rises 25 to 35 feet above the river, against which it forms a barrier, protecting a broad terrace of modified drift that lies between the limestone exposure and the foot of the bluffs. Its stratification is nearly level, the dip being about two degrees to the southeast. The beds are one to four inches thick at the top, where it has been affected by weathering; below they are four to twelve inches thick. The rock is a fine-grained compact magnesian limestone, yellowish or reddish gray, often streaked or speckled with green. Its layers are generally separated by a thin film, or sometimes by a seam half an inch thick, of dark green crumbling sandstone. The upper part of these beds in the race-way of the Hebron stone-mill contains a layer of soft sandstone one foot thick. Several quarries are worked slightly on each side of the river.

Other exposures of this limestone in the Minnesota valley are few. It is next recognized in two low outcrops, a mile apart, at the east side of Sibley county, 30 miles from Hebron in a straight line. The first is on land of Henry Young, in the south part of section 13, Jessenland, near the river and about 25 feet above it at its stage of low water. The rock is yellowish buff limestone, nearly level in stratification, in layers one to four inches thick, much divided and broken by vertical and oblique seams and cracks. Several kilns of lime have been burned from this rock. The second outcrop is owned by Walter E. Doheny, and lies in the southwest corner of Faxon, only a short distance from the town line and river. Its extent, hight, stratification, and jointed condition are nearly the same as in the last. It is a dull red, slightly arenaceous magnesian limestone. A quarry seven feet deep shows layers one to five inches thick, often separated by thin earthy seams.

Professor Winchell in 1873 described the stone at Mr. Doheny's quarry as follows:* "It is a red, metamorphic limestone, nodular, concretionary, and filled with checks and planes of separation, the thickest beds being not more than four inches, the most of them less than two, and more or less contorted. It has greenish surfaces, and isolated pockets of fine, apparently copper-stained materials, but very sparsely disseminated. It is almost a worthless stone for any use except macadamizing, owing to the ease with which the beds are fractured transversely. It is rough and irregular. It is fine-grained generally, rarely porous, and cryptocrystalline. When weathered it shows an arenaceous composition. The position of this limestone is supposed to be somewhat above that seen at St. Lawrence, and below the Jordan sandstone. It perhaps has not characters sufficiently defined and constant to be separable from the St. Lawrence. Indeed there are some good reasons for supposing it may be the uppermost portion of that limestone, considerably charged with iron and changed in outward appearance by the waters of the valley."

Jordan sandstone. Next above the last described formation is a coarse-grained sandstone, white or light gray, or often somewhat stained with iron-rust. It is usually soft and crumbling, so that it is readily excavated with a shovel; but some of its beds, quarried at Jordan, yield stone sufficiently durable for the construction of large mills and bridge masonry. It becomes harder upon exposure to the air, and its ledges sometimes have an indurated surface while they are quite friable within. The stratification is level or nearly so, in beds that vary from six inches to three feet in thickness. While each of these layers is plainly horizontal, its lamination is frequently oblique, being inclined 5° to 20°. This structure is the same with that often seen in recent sand-deposits, where the material was spread and arranged by strong currents. The direction of this inclination is variable and seems to indicate the action of tides or waves in water of no great depth. This sandstone, however, is continuous, with a comparatively uniform thickness, upon a large area, extending from the Minnesota valley eastward to the St. Croix and Mississippi rivers.

In Mankato and Belgrade this sandstone underlies a heavy magnesian limestone at the quarries upon each side of the river. These formations also occur in the same manner, forming bluffs, at Kasota, Saint Peter and Ottawa. The character of the Jordan sandstone at the Saint Peter bridge is described later in speaking of the limestone. Very extensive exposures of the Jordan sandstone are seen beside the river-road in Oshawa, extending three miles above Saint Peter. It is easily disintegrated, which often causes slightly harder layers near the top to overhang. Many excavations, used for the same

* Second annual report, p. 155.

purpose as cellars, have been made in these cliffs. This sandstone also forms the foot of the bluffs at the south side of a creek that enters the Minnesota at the northeast corner of Traverse township. At these places the sandstone rises 40 or 50 feet above the river, and is capped by limestone, less conspicuously exposed.

In Lake Prairie the sandstone is seen at several places, as in a ravine crossed by the river-road nearly opposite Ottawa, and at Patrick Osborn's and Frank Linter's, about one and a half miles farther north. Its top in all these localities is about 35 feet above the river; and at Mr. Osborn's the same limestone is seen overlying it. At and near Mr. Linter's the sandstone forms three outcrops, not protected by its usual cap of limestone. The well here, 50 feet deep, went through soil and drift, 5 feet; gray and white sandstone, 25 feet; sand, 10 feet, an unconsolidated layer of this stone; and white sandstone, as above, 10 feet; finding a good supply of water at the bottom.

Lower magnesian limestone. This formation is seen at many places overlying the Jordan sandstone. It is a magnesian limestone of buff color, often mottled in alternate red and yellow tints. The stratification is nearly level, in beds from a few inches to three feet or more in thickness. In some places, as at Kasota, in the Asylum quarry at Saint Peter, and at Mankato, a part of these beds are compact and supply an excellent stone for every purpose in building or monumental work; but generally this rock is much broken by little hollows and crevices, and is of unequal texture, some portions being especially sandy or coarse in grain, or having contorted and obscure lamination. That which is burned extensively for lime at several places along the valley in Blue Earth, Le Sueur, and Scott counties is the Shakopee limestone, and lies in higher strata, separated from this by a thin sandstone stratum.

The only observation of any rock lying upon this limestone in these counties is at the Asylum quarry, where Prof. Winchell found it covered by two feet of white friable sandstone, with a thin strip of green shale about midway in it. This may be the above mentioned thin sandstone, which is the next formation in stratigraphic order above this limestone; it may, however, be a Cretaceous deposit.

In Belgrade, opposite Mankato, about 40 feet of Lower Magnesian limestone are exposed, affording valuable quarries. In a ravine about twenty-five rods west of the principal quarry here, the underlying Jordan sandstone is seen for seven feet vertically, its top being about 30 feet above the river.

At Saint Peter this limestone, underlain by the Jordan sandstone, forms the terrace on which the city is built from the railroad bridge to the highway bridge, beyond which toward the north this terrace consists of modified drift. The plane at which the limestone rests on the sandstone descends but little if any northward within a distance of one and a half miles in Saint Peter. It is about 40 feet above the river at the railroad bridge and the Asylum, and from 40 to 50 feet at the northeast corner of Traverse township. At the highway bridge over the Minnesota the section of rock rising vertically from the river consists of a few feet of calcareous sandstone at the top, changing in its lower two feet to a nodular and irregularly laminated sandy and calcareous rock, weathering to a nearly white color, but within, at a depth of only one or two feet from the surface, dark-stained and apparently quite ferruginous, yet inclosing white bunches; then, below, one and a half feet of dull red, finely laminated, soft shale; then, the ordinary crumbling Jordan sandstone, in level beds from six inches to two feet thick, grayish white, mostly somewhat stained by iron-rust, hardest and partly calcareous in its upper layers, extending to the water, 18 feet.

Further details respecting this limestone are stated on a following page, in describing the quarries in these counties.

Cretaceous strata. A layer of clayey lignite, nearly level in stratification and one and a half feet thick, found in the east bluff of Fort creek about a third of a mile east of Fort Ridgely, was explored several years ago by a tunnel forty feet in length. The lignite is said to have been overlain and partly interstratified with a light-colored clay, five feet or more in thickness, above which was red sand. These beds form the lower part of the bluff, to a hight of 40 or 50 feet above the creek. Half a mile farther north, a layer of ochreous clay, perhaps five feet thick, partly of brick-red color and partly dark green, is found 5 to 10 feet above this creek in its east bank. Both these localities are on land of Mr. William Clark. About a quarter of a mile north from the last, on land of his son, W. H. Clark, a thin bed of nodular limestone, resembling that worked for lime-burning near New Ulm by Messrs. Winkelmann and Heimann, is exposed along a distance of a few rods in a ravine tributary to Fort creek on its northeast side. All these deposits are doubtless of Cretaceous age, and may belong to the same formations as the beds next described.

In the vicinity of New Ulm outcrops of Cretaceous strata are found in many places on each side of the Minnesota river. At John Heimann's limekiln, near the northwest corner of section 35, Courtland, the section seen six to ten feet vertically and along an extent of 150 feet horizontally, is as follows, in descending order: black gravelly soil, 2 feet; coarse drift gravel, with rounded stones up to one and a half feet in diameter, 6 inches to 1½ feet; cavernous, nodular limestone, gray in color, 1½ to 2 feet; green clay, streaked with red, 2 feet; and limestone, similar to that above, 2 feet. The last is said to be underlain by clay and shale, which were not seen exposed. The top of this section is about 35 feet above the river. Ten or a dozen rods northwest from Mr. Heimann's kiln, a section on the opposite or northwest side of the little creek which flows here, shows soil and coarse drift gravel, 3 feet; red clay, 6 inches; and red, white and green clays, interstratified, exposed about three feet vertically and seen along an extent of 50 feet, which is nearly level. The surface here is about 40 feet above the river, and thence a narrow terrace at this hight reaches some distance northwestward, due to the presence of these Cretaceous clays and limestone.

A more distinct Cretaceous terrace, thinly covered by glacial drift with many boulders of all sizes up to five feet in diameter, occurs one and a half miles south-southeast from the foregoing, in the east part of section 2, Courtland, south of the railroad. It is about a half mile long from west to east, from three to five hundred feet wide, and from 40 to 50 feet in hight above the river. Mr. Joseph Reinhart's house is built upon the edge of this terrace, and a section of its strata was afforded by his well, reported as follows, in descending order: soil and drift, 3 feet; very coarse gravel, 2 feet; yellow clay, 5 feet; blue clay, 2 feet; blue, compact limestone, 1½ feet; red clay, 1 foot; and red shale, 3½ feet; the whole depth of the well being 18 feet. The supply of water, which is good and usually plentiful, comes from its upper eight feet. This terrace is opposite Mr. Winkelmann's lime-kiln, where similar strata form a corresponding terrace at nearly the same hight. The Minnesota river, lying between them, has thus cut the lower part of its valley here through nearly horizontal Cretaceous deposits.

Eight miles below New Ulm, Cretaceous sandstone has been slightly quarried on land of William Fritz, in the N. E. ¼ of section 16, Courtland. It lies in layers from one to six feet thick, some of which contain fragments of wood, charcoal and leaves. Interstratified with these layers are others, six inches to three feet thick, of white uncemented sand. Several outcrops are found here and others appear occasionally for a mile southeastward, varying in hight from 25 to 40 feet above the river.

Professor Winchell writes of the formation at Mr. Fritz's quarry:* "It consists of alternating layers of friable sand, and hard, cemented gray sandstone, which is sometimes coarse enough to be styled conglomeritic. The section here is as follows, the upper members being somewhat displaced by the washing out of the friable layers:

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* Second annual report, p. 182.

Section in Cretaceous sandstone, N. E. ¼ sec. 16, Courtland, Nicollet county.

1.	Hard, gray sandstone, rusted in the weather, and checking into beds of about four inches,—sometimes one or two inches,	18 inches.
2.	Friable white sand,	10 inches.
3.	One course of gray sandstone, of variable thickness,	1 to 3 feet.
4.	White sand, -	6 inches.
5.	Gray sandstone, quarrying out in layers 6 to 10 inches thick, but in the quarry appearing massive; very hard, the cement appearing to be silica. It contains fragments of wood, charcoal and angiospermous leaves. Its under surface is undulatory, its thickness varying from	3 to 6 feet.
6.	White friable sand, seen -	3 feet."

The same rock occurs again on land of Henry Greenholtz, three miles farther southeast, in section 24, Courtland, and has been quarried a little for culverts and cellar walls. Its outcrop is 30 rods southeast from his house and about 35 feet above the river. There is an irregular slope at each of these localities, amounting to about fifty feet in a quarter of a mile or less, between the foot of the bluffs and the river.

The only fossils found in this sandstone in Nicollet county are scanty traces of dicotyledonous leaves and branches. No fossils are yet known from the shaly strata, with calcareous layers, which make the terraces before described, and no section has been found which exhibits the stratigraphic relationship of these formations. It is impossible, therefore, to refer them with certainty to their places in the Cretaceous series; but it seems highly probable that this sandstone, like that containing fossil leaves in Brown county (vol. I, pages 574 and 576), belongs to the Dakota group at the base of the earlier Cretaceous; while the shales, inclosing thin bands of limestone, seem likely to belong either to the Niobrara group, the uppermost of the earlier Cretaceous series, or to the later Fort Pierre group, which doubtless underlies the drift upon a large area in this state southwest of the Minnesota river, as indicated by its characteristic fossils found in digging wells in Brown, Redwood and Lyon counties.

Glacial drift. Glacial striæ were observed at three places upon the northwest part of the quartzyte in Courtland, bearing uniformly S. 25° E., with reference to the true meridian. The topographic features of the drift-sheet in this district have been described in a former part of this chapter. No portions show a well-marked morainic contour, but a somewhat more rolling surface than ordinary was observed in a belt passing north of Swan lake through Granby, Brighton and Lafayette, and a similar area is seen about High Island lake at New Auburn. The first of these tracts lies in the line of continuation of the

Elysian moraine, and the second likewise of the Waconia moraine, which are doubtless thus represented here; but their development is scarcely noteworthy, and no attempt has been made to map them in these counties.

Till, or boulder-clay, an unstratified mixture of clay, sand, gravel and boulders, constitutes the greater part of the drift formation, occasionally inclosing comparatively thin beds of stratified gravel and sand. The color of the till at a considerable depth is dark bluish, but near the surface it has become yellowish by weathering. Only one observation is recorded in these counties of till resembling that of northeastern Minnesota, this being beside the road which climbs the bluff of the Minnesota valley in section 5, Faxon, close east of the post-office. Here reddish till at least three or four feet thick was observed about sixty feet above the river. Its top was not clearly seen, but it was underlain at a definite line by yellowish till.

The boulders in the drift are mostly granite, syenite, gneiss and schist. Blocks of magnesian limestone are also frequent, and this makes up a large proportion of the gravel both in the till and modified drift. Small pieces of lignite are often found in the till in digging wells or cellars, and are sometimes noticed in the gravel of water-courses. Such fragments of lignite, probably derived from the drift, though perhaps from Cretaceous strata in place, have been observed in the bed of Little Rock or Mud creek, a few miles southeast from Fort Ridgely, and led to some search for coal along that stream.

Sections of the drift are frequently exposed in the banks and bluffs of streams, and are also excellently exhibited by well-digging, as seen in the following notes. The thickness of the drift-sheet upon these counties is about a hundred and fifty feet, so that its bottom is never reached by common wells, which usually get an ample supply of water at less than a third of this depth.

Wells in Sibley county.

Washington Lake. Patrick McGuire; sec. 30: well, 50 feet deep; soil, 2 feet; yellowish till, 15 feet; dark bluish till, 33 feet; water rose from the bottom twenty feet or more.

Jessenland. William Barge; sec. 30: well, 26 feet; soil, 2 feet; yellow till, 14; dry sand, 2 feet; yellow till, as above, 6 feet; much harder, dark bluish till; 2 feet, and extending lower. Fragments of lignite, the largest six inches long, were found in this well.

Henderson. The well at the jail in Henderson village is 50 feet deep, as follows: yellow till, 10 feet; blue till, 30 feet; and sand, with iron-rusted layers, 10 feet; water, not rising, is found in this sand at the bottom.

John Mahr's well, also in the village, is in modified drift, as follows: soil, 2 feet; sand, 9 feet; ferruginous gravel, very hard, 17 feet, containing water which does not rise, in its lower part. Gas is said to have issued from this irony gravel in such amount as to permit the workmen to remain in the well only two hours or less, and finally only fifteen minutes when near the bottom. Wells in this village vary from 20 to 50 feet in depth, and all obtain good water. In one instance a bone one and a half feet long is reported to have been found here at a depth of twenty feet, lying in gravel beneath till.

Henry Thies, in the northwest part of Henderson township, has a well 70 feet deep. This was, soil, 2 feet; yellow till, 18 feet; and then blue till, very hard and compact, picked all the way, 50 feet, containing no layers of gravel or sand. The only water found is that which seeps from the lower part of the yellow till, filling the well to twenty feet below the surface.

Green Isle. Morris Ahern, in the southwest corner of sec. 2, has a well 25 feet deep in till, yellow above and bluish below. James Davitt, in the N. W. ¼ of sec. 11, about thirty rods southeast from the last, found the yellow till 15 feet deep, below which his well went 6 feet into the harder blue till.

Arlington. August Wagner; sec. 11: well, 30 feet; yellow till at top, about 15 feet; the remainder, blue till.

Andrew Beseka; sec. 16: well, 30 feet; soil and yellow till, 10 feet; much harder blue till, 20 feet, and extending deeper. Water comes only from the upper till, and fails in a dry season.

Kelso. Abraham Chadderdon; sec. 23: well, 75 feet; soil, 2 feet; yellow till, about 15 feet; harder blue till, 58 feet; no water. Most of the wells in Kelso are only 15 to 25 feet deep, and obtain a good supply of water.

New Auburn. H. F. Palmer; New Auburn village: well, 45 feet; yellowish till, 15 feet; bluish till, 30 feet; water in sand at the bottom.

James Arnold; in the village: well, 75 feet; soil, 2 feet; yellow till, 12; sand, with water in insufficient amount, 6 inches; and blue till, 60 feet, containing no layers of sand and no water, so that this well was given up. Here and generally at New Auburn village the blue lower till can be mostly spaded, while the upper yellow till is harder and often has to be picked.

Another well at Mr. Arnold's, only twenty feet distant from the last and on ground of the same hight, went only 15 feet, passing through the upper till; from the sand beneath, water soon rose two feet, and has not failed during ten years. A few small pieces of lignite were found in these wells.

Henry Mead; also in the village: well, 60 feet; soil 2 feet; yellow till, 12 feet; sand, 6 inches, containing no springs; and blue till, 45 feet. Sufficient water seeps from the upper till, except in unusually dry seasons; none comes from the blue till below.

Dwight D. Graves; in the village, next north of Mr. Mead: well, 40 feet; soil, 2; yellow upper till, 12; sand, without water, 1 foot; and blue till, 25 feet, to a spring, probably in a thin seam of gravel and sand, from which water rose twenty feet in one day.

These wells in New Auburn village are all within a distance of an eighth of a mile. The first three are on the east side of the principal street, and the last two on its west side a little farther north. They illustrate the various fortune of well-digging in this region.

Transit. William F. Babcock; sec. 8: well, 40 feet, in about equal portions of yellow and blue till; the water seeps from the yellow upper till.

G. K. Chapin; sec. 28: well, 26 feet, all yellow till, to blue till, at the bottom, which was not dug into.

E. A. Campbell; sec. 29: yellowish till, 4 feet; sand and gravel, 20 feet; water permanent at the bottom, two to three feet deep. The country around is moderately undulating prairie, composed of till at the surface and usually to a great depth. Its swells rise ten to twenty feet above its depressions, and are frequently found to be made in part of modified drift as in this well, which is on one of the highest of the slight elevations. Probably these accumulations of modified drift were deposited beneath the last ice-sheet at the epoch of its final melting, being derived from drift which had been contained in the ice. The portion of this drift which remained in and upon the ice until the close of its melting, not being thus washed away and deposited by its streams, is here represented by the overlying till.

Cornish. A well bored 250 feet deep at the stock-ranch of Smith, Cobb and company, in the northeast part of this township, by Mr. C. E. Whelpley, of Minneapolis, is reported by him to have found yellow till, 15 feet; blue till, 215 feet, containing only one layer of sand, this being about six inches thick, at the depth of 190 feet; more compact clay, dark bluish, slightly gravelly, 15 feet; and sand, 5 feet and continuing deeper, from which water within two or three minutes rose 120 feet. Considerable wood was found in the upper foot of this sand, 245 feet below the surface.

Josiah Wakefield; sec. 4: well, 16 feet; yellow till, 15 feet; and sand, 1 foot, from which water rose three feet. Several pieces of lignite, the largest being six inches in diameter, were found in this well.

J. B. Wakefield; sec. 22: well, 21 feet, all the way in yellow till; water was found at its junction with the blue lower till, which was not dug into.

E. F. Kimball; sec. 28: well, 17 feet; yellow till, 8 feet; and yellowish sand and fine gravel, 9 feet, with water at the bottom.

J. B. Wakefield, Jr.; sec. 28: well, 20 feet; yellow till, very hard, requiring to be picked, 19 feet;

and sand, 1 foot, with water which rose two feet. This sand was underlain by blue till. Another well at this place was yellow till, 12 feet, succeeded below by blue till, which was spaded; the latter, though quite hard, was less so than the upper yellow till.

Grafton. Joseph Mingo; sec. 10: well, 35 feet; yellow till, 20 feet; blue gravelly clay, 5 feet; and gray sand and gravel, 10 feet, containing water. A knoll of gravel, ten feet above the general surface, which is almost everywhere till, occurs an eighth of a mile south of this well. The origin of such knolls of modified drift, usually found rarely here and there upon the moderately undulating surface of the drift-sheet, which elsewhere is till, but sometimes occurring frequently or even in considerable numbers, and then changing to short ridges of gravel and sand, seems to be like that of the kames of the northeastern states and of Scotland, and the eskers, as they are called, in Ireland, and the asar in Sweden. These deposits have doubtless been formed by glacial rivers flowing from the melting ice-sheet, their peculiar shape in knolls and ridges being due to accumulation in the channels or at the mouths of these streams where they were walled by ice. In most instances these masses of gravel and sand appear to have been laid down near the termination of the ice-sheet when this was retreating at the end of the glacial period; and their stratigraphic relation to the till shows that they were not often deposited beneath the ice, from which a portion of the drift that was contained in the lower part of the ice-sheet must have been dropped upon them, forming a covering of till. Sometimes, however, there seems to be proof that streams have deposited modified drift in thick lenticular beds beneath the ice, from which they have become covered by a portion of the till, as in the well last noted and at Mr. Campbell's, in Transit. The modified drift found in such situations was probably gathered by the streams from the surface of the melting ice, and deposited where these plunged through tunnels or crevasses to its bottom.

August Burgstahler; sec. 30: well, 37 feet; soil, 2 feet; yellow till, 10 feet; blue till, 25 feet; water comes in small amount from several sandy veins.

Wells in Nicollet county.

Lake Prairie. Michael Lawler; sec. 24: well, 45 feet deep; soil and yellowish till, 6 feet; dark bluish till, at first harder than the preceding, but soft and containing fewer stones below, 39 feet; no water obtained in the lower till. An iron-rusted seam, from a quarter to a half of an inch wide, ran obliquely downward twelve feet in the lower till from its top. This well was in a hollow six or eight feet below the general level of the surrounding prairie. A second well at this place, near the former and on land six feet higher, is only 12 feet deep, being all the way in the yellow till, from which much water comes in at the bottom and rises six feet. Small pieces of lignite were found in these wells.

Traverse. Xavier Fortier's well, in Traverse des Sioux village, 25 feet deep, was in the modified drift of the Minnesota valley, as follows: soil, 2 feet; yellow sand, 10 feet; bluish gravelly clay, 8 feet; yellow gravel, 3 feet; and finer yellow sand, with water, 2 feet.

W. P. McMasters; in the N. E. ¼ of sec. 7, about one and a half miles west from the last: well, 17 feet; soil, 2 feet; yellow till, 10; gravel, 1 foot, containing water, which rose one foot above this gravel; then, blue till, 4 feet, and extending deeper.

Ernst Miller; sec. 9: well, 32 feet; soil, 2; yellow till, 12; blue till, 17; and sand, 1 foot, from which water rose five feet in one day. The first three feet of this well was spaded, but all below required to be picked. Several pieces of lignite were found.

August Johnson; sec. 13: well, 30 feet; yellow till, spaded, 15 feet; harder dark bluish till, requiring to be picked, 15 feet, containing a sandy layer three feet below its top, or eighteen feet from the surface, from which water seeps in small amount, enough to become three feet deep in the well. Several fragments of lignite were found, none of them exceeding three inches in diameter.

Oshawa. The railroad well at Oshawa station, dug under the superintendence of Mr. John McAllister, of Winona, is reported by him as follows: depth, 166 feet; dark soil, 3½; yellow till, 16½; blue till, 78 feet, mostly very hard and in some layers nearly as hard as rock, but inclosing one seam of fine dry sand, three inches thick; interstratified gravel and sand, 56 feet; and quicksand, 12 feet, underlain at the bottom of the well by pebbles and rock-fragments varying in size from one inch to eighteen inches in diameter. After reaching the depth of 90 feet, the air became very impure, making lamps burn dimly, and necessitating a change of workmen every half hour; and this continued through nearly all the lower part of the well, but while digging in the quicksand at the bottom, the workmen considered the air pure. A small piece of petrified wood was found at the depth of 150 feet, in a gravel which contained very perfectly rounded pebbles. Water rose at the rate of 780 gallons per hour, and fills the well to the top of the gravel and sand.

Belgrade. B. A. Severance; sec. 3: well, 21 feet; yellow till, hard, 17 feet; darker and bluish till, soft and sticky, 4 feet; water seeps from the upper till.

A well close to the verge of the bluff in the southeast part of sec. 11, opposite Mankato, went

100 feet in till, obtaining no water, probably because the water percolating through that part of the drift-sheet is drawn off by springs which issue along the valley still lower, near the base of the bluffs.

George W. Fletcher; northwest corner of sec. 5: well, 32 feet; yellowish till, hard, requiring to be picked, 26 feet, containing occasional small bunches or pockets of sand and gravel; then dark bluish till, softer, so that it could be spaded, 6 feet; water comes from the lowest six feet of the upper till.

L. P. Parsons; northeast corner of sec. 6, about thirty rods west of Mr. Fletcher's: well, 96 feet; yellow till, about 25 feet; dark bluish till, 40 feet; and sand and fine gravel, 31 feet. This well was dug to the depth of about 30 feet and bored below. At 96 feet the auger seemed to strike a stone, on account of which a workman descended into the well to fix the shafting, and was seen to lose his hold on the shaft and fall to the bottom of the portion that was dug, being killed by breathing carbonic acid gas, with which, before unnoticed, the well had become filled. Another immediately descended to render aid, not suspecting the presence of gas, and was suffocated while still clinging to the shaft ten feet below the surface. This well yielded no water. It remained open several months. During some days the gas issued with a roaring sound at the bottom; but sometimes there was no gas in the well, so that a candle could be lowered the whole depth of 96 feet without being extinguished. At Mr. Fletcher's, also, a well which similarly failed to obtain water was dug through the till to this thick bed of sand. The same gas issued there, too, from the sand, and frequently filled the well. One evening, when Mr. Fletcher and others were examining this well, carrying a lantern, on their going past the leeward side the draft of gas extinguished the lantern instantly.

Granby. John P. Schafer; sec. 7: well, 20 feet; yellow till, spaded, 16 feet; coarse sand, 1½ feet; and blue till, very hard, dug into 3 feet, and extending lower. Wells in this vicinity are 15 to 30 feet deep, with water plentiful and good.

John Burk; sec. 13: well, 63 feet; yellow till, 16 feet; dark blue lower till, much harder, 47 feet, containing at the depth of 60 feet a layer softer and more sandy than usual, below which was the ordinary very hard blue till. This well obtained no supply of water.

Nicollet. William Randall; S. E. ¼ of sec. 36: well, 25 feet; soil, 2; yellow till, 23; water seeps, is permanent and of good quality.

Brighton. Valentine Karpen; sec. 10: well, 25 feet; yellow till, 22 feet, containing thin seams and veins of whitish calcareous matter, and inclosing several layers of sand, up to six inches in thickness; then dark bluish till, 3 feet, not much harder than the upper till. Well-borers often find the lower till easier to bore than the upper, because of the greater number of stones in the latter.

Lafayette. John Simmet; sec. 9, in the south part of this township: well, 25 feet; soil, 2 feet; yellow till, 18; much harder blue till, 5; water rose one foot from a vein or spring at the bottom. Several small pieces of lignite, up to three inches in diameter, were found in this well. Another well on Mr. Simmet's farm, an eighth of a mile farther west, was yellow till, 15 feet; dark bluish till, 10 feet; and sand of same color as the lower till, with plenty of water, 5 feet.

Conrad Dirks; sec. 10, in the south part of the township: well, 20; yellow till, 13; blue till, 7.

West Newton. Aleck Harkin; sec. 30, in the Minnesota valley at the base of the bluff: well, 42 feet; gravel and sand, washed from the bluff, mostly blackened like the surface soil, 20 feet; yellow sand, 20 feet; and irony gravel, with water, 2 feet. Another well on Mr. Harkin's land, situated at the top of the bluff, a third of a mile farther north, is 15 feet deep, being all the way in yellow till, which here contains frequent whitish veins and concretions of calcareous matter; water much harder than that of the foregoing well, seeps from this till.

The Hospital well, Saint Peter. Through the co-operation of Dr. C. K. Bartlett, superintendent of the hospital for the insane, the following record has been obtained of this well: It was drilled in the fall of 1885. This well begins at the foot of the river-bluff, not far above the level of high water of the Minnesota river. There had before been excavated here a reservoir for water and a pump-house erected for throwing the water to a higher level, for the use of the hospital. This reservoir was fed by springs issuing from the sandstone, of which the bluff is mainly composed. At the depth of 116 feet the water began to flow over the top of the pipe, which was driven into the rock to protect the drill, and rose above the ground about two feet. The flow gradually increased to the bottom of the well, which is 200 feet below the point of beginning. The water will rise in a tube seven feet above the ground, or some ten feet above the original level of the reservoir, and at least twenty-five feet above the level of low water in the river. This record is valuable, as it throws light on the stratigraphy of the upper part of the Cambrian in that part of the state. The record furnished by Dr. Bartlett is as follows:

1.	Gravel and loose rock,	15 feet.
2.	Sandrock (Jordan), - - - - - - - - - -	65 feet.

3.	Pink limestone (St. Lawrence),	70 feet.
4.	Gray sandrock, hard,	15 feet.
5.	Pink limestone rock,	10 feet.
6.	Red sandrock,	22 feet.
	Total,	197 feet.

Terraces of till. In addition to the general description of the valley of the Minnesota river, in a former part of this chapter, a few details, respecting narrow terraces sculptured in the till, claim notice here. The bluffs of this valley, excepting occasional rock exposures at their base and several extensive terraces of modified drift, are composed of till which generally rises in a nearly straight slope; but a narrow terrace, wrought in this slope of till, was noted near Fort Ridgely, in West Newton, and at Hebron. A half mile southwest of Fort Ridgely, near the east edge of section 1, such a terrace, about seventy-five feet above the river, extends an eighth of a mile, being only a few rods wide. It is abundantly strown with boulders up to five feet in diameter, and thus resembles the bench or terrace very frequently seen on the bluffs along the upper fifty miles of this valley above the Yellow Medicine river, where it appears to be produced by a rocky stratum in the drift, which is probably a buried moraine. The bluffs from the Yellow Medicine river to Fort Ridgely, though rarely showing any such terrace line, are generally quite rocky with boulders of granite, gneiss, schists, and limestone; but from Fort Ridgely to New Ulm and Hebron, the bluffs bear scarcely one-twentieth as many boulders, which occur only in the sparingly scattered number usual in the till of Minnesota.

For a distance of about six miles through West Newton, the bluffs of the Minnesota valley, 180 feet high, are marked by a continuous narrow terrace, apparently sculptured in the till, from 125 to 100 feet above the river. This terrace and the bluffs above and below have no greater number of boulders than the drift everywhere, and in many places the terrace is thinly covered by gravel and sand. It seems to indicate that the river, in gradually shifting its channel during the process of excavating its valley, here one and a half miles wide, first swept from the north to the south side of the valley, forming a broad hollow one-third to one-half as deep as the present valley; and that subsequently it has moved again northward and from side to side, undermining and carrying away every part of this bed except its northern margin.

The only other terrace of this kind observed in these counties is on the bluff north of Hebron, extending two miles in sections 29, 28 and 27, Nicollet, and varying from a few rods to an eighth of a mile in width. The bluff here is about 180 feet high, and the terrace slopes eastward in its length of two miles from about 150 to 125 feet above the river. The face or slope below the west half of this terrace is abundantly strown with boulders, and this is their first occurrence in unusual quantity upon the bluffs below Fort Ridgley. Boulders are also abundant within a half mile south on the west portion of the lower terrace, which is composed of St. Lawrence limestone, 35 feet above the river, and again on a somewhat higher terrace of this formation two miles southeast on the south side of the river.

Further notes of terrace-like erosion in the till are presented in the description of the "sand prairie" near Saint Peter, where the modified drift is in part underlain by a bench of till with a great profusion of boulders.

Modified drift. The foregoing list of wells includes a considerable number which consist partly or wholly of modified drift. Under this name are included all the deposits of gravel, sand, and clay or silt, which were formed by the waters that were discharged from the melting ice-sheet. Such deposition took place more or less along the ice-margin, and in the valleys of rivers flowing thence, throughout the glacial period, but became especially wide-spread and rapid during the epoch of recession and final dissolution of the ice at the close of this period. Notes of interesting kame-like accumulations have been already given in the description of wells in Transit and Grafton.

Many features of the drift in this and adjoining states indicate that the ice age was marked by two principal epochs of glaciation, separated by an interglacial epoch of comparatively warm climate. In the report of Brown county (vol. I, page 582) mention is made of a bed of modified drift seen in the upper part of the bluff of the Minnesota valley southwest of New Ulm, having a thickness of eighteen feet, which was probably deposited at the close of the earlier glacial epoch, over which lies eighteen feet of till, regarded as the deposit formed by the later ice-sheet. A much thicker bed of modified drift, which may belong to the same interglacial epoch, was found ten miles farther east, in the S. W. ¼ of section 11, Courtland, where Carl Richert bored 100 feet for a well at his house, finding soil, 2 feet; yellow and gray till, 30 feet; yellow sand, becoming nearly white in its lower part, 54 feet; and yellow gravel, 14 feet. No water was found in this boring, and at last the caving in of the sand and gravel made it impossible to extricate the auger, and the work was given up. This was on the average level of the country all around, being distant an eighth of a mile or more from the bluff of the Minnesota valley, at a hight some 200 feet above the river.

In section 5, Faxon, the bluffs of this valley, rising close against the river to a hight of about 150 feet, are composed mainly of till, overlain by scanty beds of gravel and sand. Fifty feet below their top, clay in layers two to three inches thick, separated by dark partings as at Carver, is exposed for five feet vertically and three rods horizontally, in a gully at the east side of the road. It is of small amount, lying on a reddish imperfectly stratified gravel, nearly like till. The bluff below is chiefly till, but in some portions incloses thick beds of stratified drift. A gully about fifteen rods west of the post-office shows a level stratum of gravel and sand, 30 or 40 feet thick, with its top some 75 feet above the river, overlain by till.

Terraces of modified drift. Very interesting terraces, composed of stratified gravel, sand and clay, occur in the valley of the Minnesota river from the vicinity of New Ulm to its mouth. They are remnants of the deep flood-plain of modified drift that was deposited by the river Warren while the last ice-sheet was melting from this region.

In Courtland such terraces are finely exhibited opposite the southeast part of New Ulm, and again beginning about two miles farther southeast and extending five miles. The first of these lie mainly in section 27. The schoolhouse near the east line of this section stands upon the edge of the bluff of till, about 180 feet above the river. Next southwest is a steep descent of forty feet to a terrace of stratified gravel and sand, an eighth of a mile wide and fully a mile long from northwest to southeast. An escarpment then falls thirty feet more to another terrace of modified drift which extends a half mile from northwest to southeast through the middle of section 27, its width being from 300 to 500 feet. Mr. Daniel Dingler's house is built on the edge of this terrace, from which the descent is first steep for fifty feet and then moderately sloping to the bottomland, five to fifteen feet above the river. A little farther to the southwest in this section are the outcrops of conglomerate and granite before described. These terraces of modified drift are approximately 140 and 110 feet above the river, being much higher than the Cretaceous terrace which lies next southeast at a hight 35 to 40 feet above the river. From one to two and a half miles farther southeast is a conspicuous outcrop of red quartzyte, rising about 125 feet above the river, and projecting fully a half mile into the valley from its northeastern bluff. Sheltered in its lee is a magnificent terrace of modified drift, reaching four miles down the valley, from the east part of section 1 to the north line of section 15. Its width along this entire extent varies from a fourth to a third of a mile. This is a very level tract, 50 feet below the bluffs of till at its northeast side and 150 feet above the river, a quarter to a half of a mile distant at the southwest, toward which the first hundred feet of descent is by a steep escarpment. Wells show that the material of this terrace is sand and gravel. There can be no doubt that the valley here has been filled with modified drift to the level of these terraces, constituting an old flood-plain of the river, 140 to 150 feet above its present level. A remnant of this modified drift, underlain by Cretaceous beds, forms the plateau upon which the southwest part of New Ulm is built; and another extends a mile upon the southwest side of the valley in the north part of Cambria, opposite the southeast end of the long terrace in Courtland, and of nearly the same hight.

The "sand prairie" west and northwest of Saint Peter is a conspicuous remnant of this old flood-plain. This terrace is from three-fourths to one and a half miles wide, and extends from the asylum for the insane, in section 31, Oshawa, four miles north to the north part of section 5, Traverse. Its hight is about 150 feet above the river, and 75 feet below the general level of the till which covers the country westward, to which the ascent is by steep bluffs at the west side of the "sand prarie." The depth of this modified drift, consisting of sand and gravel, sometimes with layers of clay, is, in the central portion of its area, 50 to 80 feet, as shown by wells, which find till below.

Examples of the sections found in digging wells on this terrace are as follows:

John Bacquet; sec. 8, Traverse: well, 90 feet; sand and fine gravel, 80 feet; and yellowish gray till, 10 feet. This well was at first dug 87 feet, at which depth it became dry during a drought. It was then dug three feet lower, where water was struck, rising three or four feet and standing permanently so.

John McCurdy; sec. 17, Traverse; well, 53 feet; sand and fine gravel, 50 feet; and bluish till, 3 feet.

Casper Baberich; in the east edge of sec. 18, Traverse: well, 62 feet; soil, 2 feet; yellowish sand and gravel, 28 feet, with water in its lower part; dark bluish clay, 1 foot below which the water coming from above was lost; and gravel and sand, yellowish, the same as above, 31 feet, containing water at the bottom.

At the south end of this terrace-plain and through Saint Peter the first descent from it toward the river is a steep escarpment that falls fifty to seventy-five feet, becoming a gradual slope below, to the terrace of limestone, underlain by Jordan sandstone and mainly covered by drift, upon which the city of

Saint Peter is built, 25 to 60 feet above the river. Gustavus Adolphus college of the Swedish Lutheran church is prominently located on the edge of the terrace of modified drift. The asylum is nearly a mile southwest from the city on the lower terrace. The south end of the "sand prairie," lying close west of the asylum and seventy-five feet above it, has only a thin covering of modified drift, which rests on till. The very abundant boulders of all sizes up to five or six feet in diameter which strow the verge of the "sand prairie" along an extent of about two hundred feet at an eighth of a mile north from the asylum, appear to belong to a projecting point of till, though the escarpment below and at each side and the terrace extending from it westward are sand. An excavation fifteen rods west from this point shows soil, 2 feet; sand, 6 feet; very coarse gravel, 2 feet; and gray or yellowish till, not unusually rocky, 8 feet. Fig. 13 is a sketch showing the probable relation of the till and modified drift here. Farther north the verge of the escarpment is modified drift, but its lower portion shows frequent patches of boulders, the upper limit of which is found at a decreasing hight as we go northward. These boulder-covered spots are very notable southeast and east of Gustavus Adolphus college, lying forty to sixty feet below the top of the terrace. Very large springs issue here and appear to mark the line of junction between the till and the overlying modified drift, which, however, often covers the slope or face of the terrace below these patches of boulders.

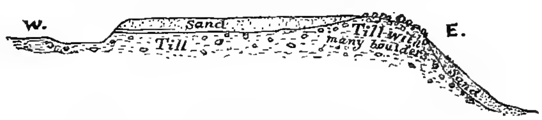


FIG. 13. SOUTH PART OF THE "SAND PRAIRIE."

The preservation of the "sand prairie" thus appears to be due in part to the protection from erosion by the river which was afforded by a prominent spur of till that underlies it at its south end and through Saint Peter. In like manner, the preservation of the long terrace of modified drift in Courtland is attributable to the outcropping quartzyte at its upper end, which warded off the current of the river; a projecting point of till in the northeast quarter of section 17, Kasota, sheltered the south end of the similar terrace which reaches thence three and a half miles northward; the Le Sueur prairie remains because it occupies a bay in the eastern bluffs of the valley, and the areas of modified drift of Belle Plaine and Spirit hill west of Jordan have a somewhat similar position; and, lastly, the southwest end of the modified drift terrace at "Shakopee prairie" was guarded from being washed away by the terrace of limestone at the Louisville lime-kilns. Some other remnants of this ancient flood-plain of modified drift were fully exposed to the river's erosion, but have yet escaped; as the plateaus of New Ulm and the "sand prairie" northwest of Jordan, and the terrace opposite the last in Carver county.

Northward from Saint Peter, at the west side of Traverse des Sioux, the descent from the "sand prairie" to the river is at first a gentle slope, to a nearly level terrace which is about forty feet lower and an eighth of a mile wide, and reaches a half mile or more from north to south. These areas are stratified gravel and sand without boulders. Descending some seventy-five feet more by a gradual slope of modified drift, we come to the terrace of Traverse des Sioux, 50 to 60 feet above the river. This is composed of drift at the surface, which is principally stratified gravel, sand and clay, but at many places is abundantly strown with boulders of all sizes up to six feet and very rarely ten feet in diameter. This terrace is the continuation northward of that on which Saint Peter is built, where also it frequently shows many boulders and is underlain by the Cambrian rocks.

In Sibley county considerable vestiges of the ancient flood-plain of modified drift in the Minnesota valley occur as narrow terraces, composed of stratified gravel and sand, about 150 feet above the river. One of these extends nearly two miles from southwest to northeast in sections 34, 27 and 23, Henderson, being about a quarter of a mile wide. Its surface is somewhat undulating, instead of being a flat plain such as usually forms the top of these terraces; and its hight at its margin next to the river averages ten feet above its west side next to the slope of till, which rises fifty or sixty feet higher. On the east, in descending to the river, the lower half of the slope next to the bottomland is also till. Another terrace of this modified drift, having about the same hight, and extending a mile or more in length from west to east and a quarter of a mile in width, lies southeast of the road in section 33, Faxon.

Alluvium. The alluvial bottomland of the Minnesota river through these counties is mainly from an eighth to a half of a mile wide, but in some places is cut off by the river's course and left wholly on the opposite side. Its hight is principally 10 to 20 feet above the river. It is only overflowed in small part by ordinary floods; but is wholly covered by the extreme high water, which comes once in five or ten years. By each overflow a very thin layer of clayey and sandy silt is deposited upon the flood-plain, which has been built up in this manner during the recent epoch. This alluvium is used for brick-making, and the excavations in it often show layers filled with fresh-water shells like those now living in sloughs throughout this region; and in some other parts land-shells are occasionally found. The lakelets and sloughs which are noticed at many places in the bottomland are portions of ancient channels, forsaken by the gradual shifting of the river's course or sometimes by its cutting across the isthmus at the base of a circuitous bend. Along the foot of the bluffs fan-shaped deposits of gravel and sand, 10 to 30 feet deep, have been spread upon the bottomland by rills and springs which have cut gullies in the bluffs.

MATERIAL RESOURCES.

Agriculture, which has been spoken of in an earlier part of this chapter, is the principal industry and source of wealth in these counties.

Water-powers are available on High Island creek, Rush river, and Nicollet creek. The head on the last named stream at the Hebron stone mill, owned by Mrs. J. H. Dunham, is twenty feet.

Building stone. The granite quarried for building Fort Ridgely has been already described. No quarrying has since been done at that place, nor elsewhere, at least to any considerable extent, in the granite and gneiss of western Nicollet county.

In the quartzyte of Courtland, two to three miles below New Ulm, quarries are owned by Francis Baasen, about thirty rods southeast from the railroad bridge, who formerly quarried $200 worth of stone yearly, but none during a few years past; William Winkelmann, a few rods further east, quarrying only for his own use in building; Frederick Meierding, a little farther east, lately selling $100 worth yearly, formerly about $400 yearly; Gottlieb Arndt, one-fifth of a mile northeast from the last, with annual sales from $50 to $300; and Joseph Reinhart, close east of the last, selling little now, formerly $300 worth per year. Only rough stone of small dimension is obtained, bringing from $2 to $3 per cord.

In the St. Lawrence limestone at Hebron, in the south part of Nicollet township, quarries are owned, in order from west to east, by Mrs. J. H. Dunham, William H. Thurston, William J. Phillips and Abel Keen. Some of these are rented at fifty cents per cord. The stone is sold for $3 per cord, and the extent of sales at each quarry varies from $100 to $300 yearly. Judson, opposite Hebron, and Jessenland and Faxon in Sibley county, also have small quarries in this formation.

The Lower Magnesian limestone is extensively quarried in Belgrade, opposite Mankato, where three quarries on land of John Q. A. Marsh and brother are rented mostly to Dennis Sullivan and John Duffee, who pay fifty cents per cord, selling at about $2 per cord for rough stone. A little farther west, Andrew M. Weimar owns a quarry, opened in 1878. He supplies dimension stone, rough or hammered. The rock of these quarries is evenly colored and compact, in thick beds, and can supply blocks five by four by two feet, or slabs eight feet long.

At Saint Peter this limestone is thinly bedded, except in the asylum quarry, where it lies in massive beds one to four feet thick. This quarry has been worked principally for the asylum buildings. The other quarries are owned or worked by Jacob Bauer, Hugh Brogan, Ubalt Drenttel, John Malgren, and Henry Miller. Their annual product is fifty to two hundred cords each, selling at $1.50 to $3 per cord.

Cretaceous sandstone has been quarried slightly for culverts and cellar-walls in Courtland, eight and eleven miles southeast from New Ulm; but the business is now discontinued or very small.

Lime. Cretaceous strata in the vicinity of New Ulm, and the Shakopee limestone in the lower Minnesota valley, yield important supplies of lime. This is mostly burned, however, on the south and east side of the Minnesota river. North of this river, in Courtland about a half mile north of the Redstone railroad-bridge, John Heimann burns lime from nodular Cretaceous limestone. His yearly product is from 1,000 to 1,500 barrels, sold at $1 per barrel. This lime is strong and sets quickly, making a white plaster; except that it commonly includes a little clay, it is quite pure, having no magnesia or sand.

The St. Lawrence limestone in section 13, Jessenland, has been used for lime-burning by Herman Matthei, brick-maker at Henderson. Five kilns of small size were burned near the Jessenland quarry in 1878, but the stone has since been teamed to Henderson before burning. The lime brings sixty cents per barrel.

Drift boulders of magnesian limestone are burned for lime by Henry Hensler near the west end of Silver lake in Jessenland, producing 200 to 300 barrels yearly. This lime is mostly used by John Meier, brick-maker and mason, at Henderson. Lime has also been burned from boulders at New Auburn and about Swan lake.

Bricks. In Henderson bricks are made near the north edge of the village by Herman Matthei, who began thirteen years ago, and has averaged about 400,000 yearly; and near the south edge of the village by John Meier, who began in 1878, and has made about 300,000 yearly. Both use the recent alluvium of the Minnesota river, which is a dark clayey silt fifteen feet or more in depth with its surface five to fifteen feet above low water, mixing with it about one-sixth as much sand, producing bricks that vary in color from reddish when moderately or slowly burned to yellowish brown or cream-colored when subjected to more intense heat in burning. The price is $5 to $6 per thousand.

In Oshawa, about one mile southwest from Saint Peter, Matthias Davidson has made bricks twenty-three years, using also the recent alluvium of the river, mixing with it one-fourth as much sand. He averages 400,000 yearly, and sells at $4 to $7 per thousand. The surface at the excavation is 15 to 18 feet above low water; at the top a thickness of three or four feet, being too sandy, is rejected; the next ten feet, consisting of dark, levelly stratified, fine clayey silt, are used for brick-making; four feet lower, at 18 feet below the surface, this deposit changes to coarse gray sand and gravel containing much limestone. A layer full of fresh-water gasteropod shells, like those of the neighboring sloughs, occurs about five feet below the surface in this excavation, being continuous through its whole extent of about a hundred feet. A slough existed once at this level; but above and below this stratum are occasional land shells (*Helix*), indicating a deposit accumulated by freshets, as in spring, and left dry during the rest of the year.

At the north end of the "sand prairie," in the N. E. ¼ of section 5, Traverse, south of the creek, red bricks of good quality were made during several years by John McCurdy, chiefly while the asylum was being built, a large part of his product, which was 1,000,000 yearly, being used in its construction. The clay lies about 100 feet above the creek and some 30 feet below the "sand prairie," which supplied the sand used for tempering. In the excavation only two or three inches of sward and soil at the surface were wasted; and thence the stratum of clay used for brick-making reaches to a depth of eight feet, the upper four feet being yellowish and requiring an intermixture of one-third as much sand as clay, and the lower four feet dark bluish, needing much more sand, so that often sand and clay were mixed in equal amounts. No limy concretions occur in the yellow clay, but they are found in the lower blue clay, being most frequent in its upper six inches. Next below this clay a well went through 45 feet of sand and fine gravel to water in quicksand.

The bricks used in building Fort Ridgely were made about a quarter of a mile northeast of the fort, from a bed of clay, perhaps of Cretaceous age, in the west bluff of Fort creek.

Brick-making has been attempted near the west end of lake Erin, in Washington Lake township, but unsuccessfully because the bricks were cracked after burning by particles of lime due to limestone gravel in the material used.

Springs occur frequently in the ravines which indent the bluffs of the Minnesota valley, and at the foot of these bluffs along the margin of the bottomland. They are especially numerous and copious beside the road in section 1, Oshawa, and section 12, Belgrade, at a hight about 40 feet above the river. A notable ravine, a third of a mile or more in length and 150 feet deep, has been cut by these springs in the N. E. ¼ of section 1, Oshawa, but so long ago that it is occupied by woods of large growth.

Aboriginal earthworks. Several small artificial mounds of the ordinary dome-like form, reported to have been grave-mounds of the Sioux, formerly existed within an eighth of a mile north and northwest of Fort Ridgely, but were removed for grading.

CHAPTER VI.

THE GEOLOGY OF McLEOD COUNTY.

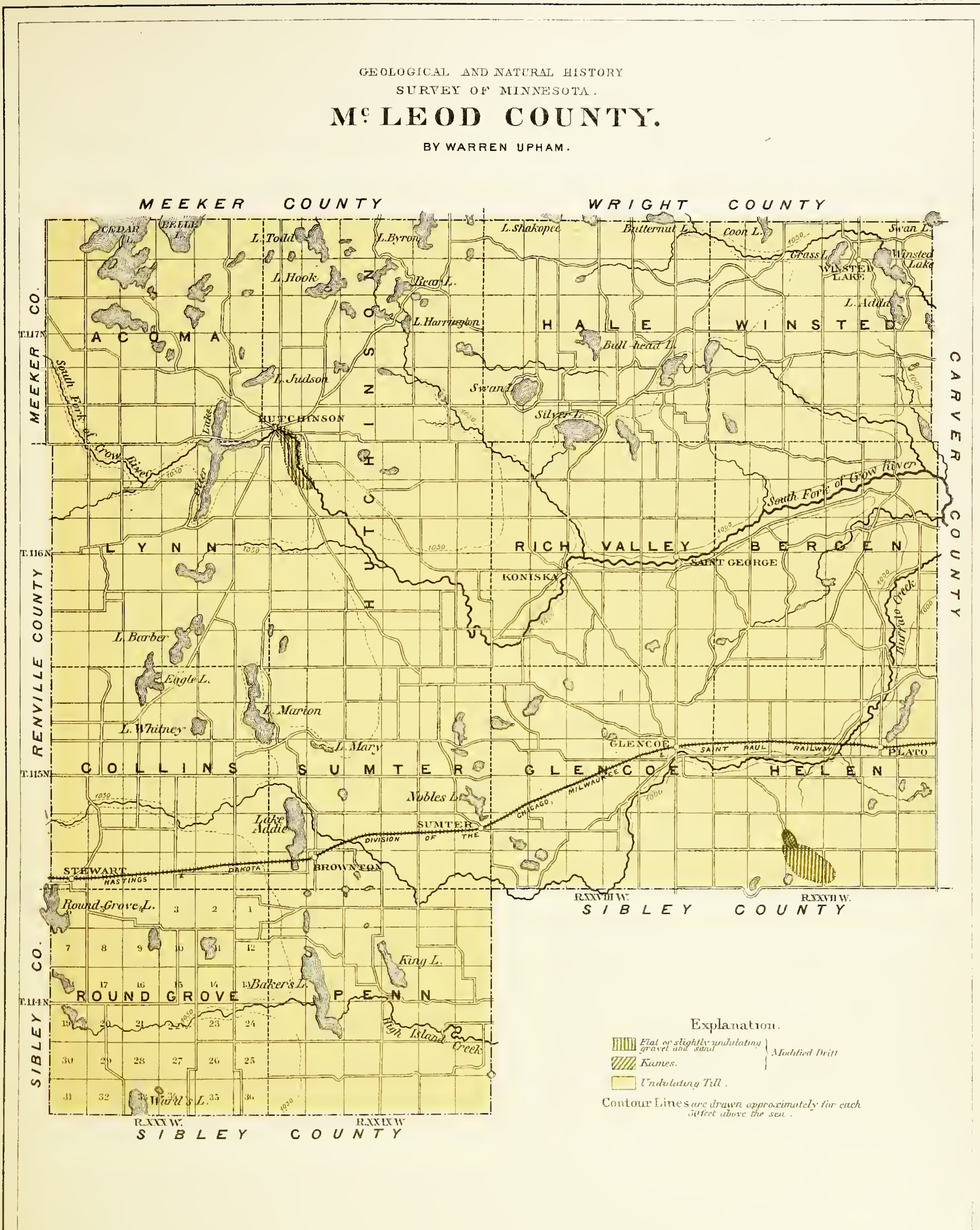
BY WARREN UPHAM.

Situation and area. McLeod county (plate 37) is situated in the central portion of the south half of Minnesota. Glencoe, its county seat, is about fifty miles west-southwest from Saint Paul and Minneapolis. The length of McLeod county from east to west is 24 miles, and its western part has the same extent from north to south, but its eastern part lacks two townships at its south end, being thus left 18 miles wide. The area of McLeod county is 507.45 square miles, or 324,771.86 acres, of which 14,283.23 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county lies almost wholly within the basin of the South branch of the Crow river, which flows through its northern half from west to east. Three or four small tributaries join it from the north in McLeod county, but none of considerable size from the south. Buffalo creek, which drains the southern part of this county, unites with the South branch of Crow river about three-quarters of a mile east of the boundary which separates McLeod from Meeker county. In the driest seasons this creek at Glencoe, twenty-five miles from its source, is reduced to a series of stagnant pools, which are filled with marsh grass and other aquatic plants.

Lakes occur frequently in all parts of this county, but are most plentiful in its northern tier of townships, especially in the north part of Hutchinson and Acoma. Cedar lake, lying partly in Meeker county, includes also an area exceeding two square miles in Acoma. Belle lake, situated a short distance farther east, and similarly crossed by the county line, has a length of two miles from north to south, with a maximum width of about one mile. Otter lake, with an outline like a cross, extends three miles from north to south, lying in Acoma and Lynn townships, and its arms reach two miles from west to east along the course of the South branch of the Crow river. In Hutchinson lakes Byron, Todd and Hook are each more than a mile long. Silver, Swan and Bullhead lakes in Hale, Winsted lake and lake Adda in Winsted, King's lake in Penn, Nobles lake in Sumter, lake Barber in Lynn, Eagle lake and lake Whitney



Julius Bien & Co. lith.

in Collins, Round Grove lake, at the northwest corner of Round Grove township, and Ward's lake crossed by its south line, have each a length of about one mile, their longer axes trending in most cases approximately from north to south.

Lake Marion, lying mostly in sections 1 and 12, Collins, lake Addie at Brownton, and Baker's lake in Penn, are each about two miles long from north to south, but do not exceed a quarter or a third of a mile in width. It is noteworthy that these, and the similarly prolonged and narrow Otter lake, form a continuous and almost straight series, extending seventeen miles, more than half of which is water.

An ice-formed ridge occurs on the north side of the west part of Silver lake, in Hale. It extends about a sixth of a mile and is four to six feet high, being narrow with steep sides. Its material is in part gravel and sand, but it also includes considerable clay and contains boulders up to three feet in diameter. Another ice-formed ridge, about three feet high, was noticed on the northeast shore of the lake in the south part of section 29, Glencoe, near the group of aboriginal mounds mentioned on a following page.

Topography. The contour of McLeod county is nearly everywhere moderately undulating, with long slopes rising in swells 10 to 20 or 25 feet above the depressions or sloughs. Scarcely any contrast in the general outlines of the surface is notable in a comparison of the wooded with the prairie areas. At the town of Glencoe and for several miles westward the land is approximately level, differences of more than ten feet in hight between the most elevated and the lowest portions being rare. A tract somewhat more undulating than the average lies in the west edge of Sumter, between lakes Marion and Addie. In Collins the swells are mostly 10 to 15 feet above the sloughs, some of which are of considerable extent and have accumulated a bed of peat on their bottoms. Prairie fires in 1871 ignited one of these peat deposits in section 15 and the north part of section 22, Collins, burning it to a depth of one or one and a half feet over a space of several acres.

The lakes of the county are mostly bounded by gentle or often steep slopes which ascend 10 to 30 feet to the average surface of the surrounding district. The South fork or branch of the Crow river lies in a valley, eroded 30 to 40 feet below the general level and from a fourth to a half of a mile wide. Buffalo creek in the west part of Collins has excavated its valley to the depth of 20 or 25 feet, with a width of about thirty rods; at Glencoe this valley continues with about the same depth, but averages a quarter of a mile in width.

Elevations, Hastings & Dakota division, Chicago, Milwaukee & Saint Paul railway.

From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from Hastings.	Feet above the sea.
Plato,	68.5	
Buffalo creek, bottom, 964; grade on bridge,	69.5	981
Summit, cutting 5 feet, grade,	73.5	1019
Glencoe,	74.0	1006
Peat marsh, grade,	76.0	1027
Sumter,	79.9	1035
Depression, grade,	81.9	1012

	Miles from Hastings.	Feet above the sea.
Summit, grade,	83.2	1036
Gravel pits, grade,	84.0	1020
Buffalo creek, water, 1005; grade,	84.2	1019
Brownton,	84.4	1024
Lake Addie, water, 1007; grade,	84.9	1019
Summit, grade,	87.1	1057
Depression, grade,	87.4	1049
Summit, grade,	90.9	1074
Stewart,	91.4	1064

A preliminary survey made by E. S. Alexander in November, 1877, for a proposed railroad from Minneapolis to Hutchinson, gives the following elevations in this county:

	Miles from Minneapolis.	Feet above the sea.
Winsted lake, bluff 18 feet high, water,	44.6	996
High ground,	46.9	1037
1400 feet west of the southeast corner of section 28, Hale, a half mile north of Silver Lake post-office,	54.0	1062
High ground near Swan lake,	55.3	1085
Swan lake,	56.0	1047
Divide of land,	56.4	1077
Bear creek,	57.5	1048
Boundary of the Big Woods, edge of prairie,	58.6	1069
Bluff east of the Crow river,	61.7	1079
Crow river, low water,	62.1	1031
Hutchinson,	62.4	1044

The highest land in McLeod county is 1,075 to 1,100 feet above the sea; and its lowest land, where the South fork of Crow river, and its tributary, Buffalo creek, cross the eastern boundary, is about 950.

Estimates of the average hights of the townships of this county, as indicated by the contour lines on the map, are as follows: Winsted, 1,020 feet above the sea; Bergen, 1,000; Helen, 1,000; Hale, 1,060; Rich Valley, 1,025; Glencoe, 1,010; Hutchinson, 1,060; Sumter, 1,025; Penn, 1,025; Acoma, 1,075; Lynn, 1,060; Collins, 1,050; and Round Grove, 1,050. The mean elevation of McLeod county, derived from these figures, is approximately 1,040 feet above the sea.

Soil and timber. Unmodified glacial drift, called till, forms the surface of this county almost universally. It consists mostly of clay, with which boulders, gravel and sand are more or less intermingled. The upper foot or more of this deposit, commonly called the soil, has been blackened by the decay of vegetation, being thereby enriched and its fertility much increased, as compared with the yellowish subsoil, which is the same gravelly clay. The thickness of this black soil averages fully one foot, and in many places, especially in depressions and in valleys, it is often two or three feet deep. Its depth and its productiveness are nearly the same in the wooded and in the prairie portions of the county. The chief crop of this district, as generally throughout Minnesota, is wheat. Corn, oats, hay, sorghum, potatoes, garden vegetables and small fruits, are also raised, mostly for home use. Besides wheat, the farmer's income by sale and exportation comes mostly from stock, as horses, neat cattle, hogs and sheep, and from dairy products.

Timber covers about half of McLeod county on the northeast, this being a portion of the Big Woods. Its western boundary runs from Cedar lake, at the northwest corner of this county, southeasterly by Hutchinson and along the northeast side of the South branch of Crow river to the northeastward bend of this stream in the southwest corner of Rich Valley township; thence, crossing the South branch, it extends two or three miles south, and next is deflected six or seven miles, first in a northeasterly, then in a southeasterly course, to sections 7 and 18, Helen, close east of Glencoe; and farther south, after crossing Buffalo creek, it trends southwesterly, so that the wooded area includes the portion of Glencoe at the southeast side of this creek.

West of this line, timber is only found in small groves beside the lakes, the country being, with these exceptions, all natural grassland, or prairie, ready for the plow, seeder and harvester. Before cultivation the prairie affords excellent pasturage, but its yield of hay is generally less than a half ton per acre; and the chief supply of hay cut by the pioneer farmers is from the frequent sloughs, or level marshy tracts, from a few rods to a half mile or more in extent, which produce a ton or more per acre, coarser and of poorer quality than the native grasses of the upland. These hay marshes are also plentifully scattered throughout the timbered area. After cultivation, the uplands, when sown with timothy and redtop grasses, produce one to two tons per acre.

The following species of trees and shrubs were noted in McLeod county: basswood, soft or silver maple, white elm and red or slippery elm, ironwood, the American aspen or poplar, black and red raspberries, prickly ash, and hazel, abundant; wild plum, butternut, the black, bur and white oaks, cottonwood, willows, smooth sumach, black currant, and both the prickly and the smooth wild gooseberries, common; sugar maple, box-elder, black cherry, white ash, hackberry, bitternut, choke-cherry, elder, and bush cranberry, frequent; and red cedar, rare, observed only at Cedar lake.

GEOLOGICAL STRUCTURE.

Glacial drift. No outcrop of the rocks underlying the drift occurs in this county, nor are they reached by wells. Till, as before remarked, covers all the county, being spread in a sheet which has a smoothly undulating or approximately level contour. Its average thickness may be as great as in the railroad well at Stewart, where it reaches from the surface to the depth of 260 feet; but more probably in some other parts of the county it would be found not more than 150 feet thick, which seems to be approximately its average upon the western two-thirds of this state.

The till is an unstratified deposit of clay, sand, gravel and boulders, mixed indiscriminately together. Very finely pulverized rock, forming a stiff, compact, unctuous clay, is its principal ingredient, whether at great depths or at the surface. The admixture of sand and gravel is somewhat variable, being often greater in the lower than in the upper part of the till. It is rarely enough to cause the side of a well or cellar to fall down at the time of excavation. The upper portion of the till, to a depth that varies from a few feet to 20 or 30 feet, or rarely more, has been changed from the dark bluish color which prevails at a greater depth to a yellowish color, this difference being due to the effect of air and water upon the iron contained in this deposit. Layers of sand and gravel are frequently inclosed in the till. They are commonly from a few inches to a few feet in thickness, and often are filled with water. At considerable depths the water is generally under hydrostatic pressure, which causes it to rise in wells.

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 larger size are less frequent, and often a well or even a railroad cut in till fails to display any of greater diameter 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 in the upper part of the till than below.

Most of the boulders and pebbles in this part of the state are granite, syenite, gneiss, and the crystalline schists. Blocks of whitish or buff magnesian limestone are also frequent, and, though constituting but a small percentage of the whole, are gathered in considerable quantities for lime-burning. The same stone forms a somewhat larger proportion of the gravel in the till and modified drift, and in the recent alluvium of streams. This limestone appears to be the same that is generally observable as an ingredient of the drift throughout western Minnesota. Its nearest outcrops, in the direction whence the drift has been transported, are near Winnipeg, in Manitoba. One of its boulders in McLeod county deserves mention for its large size. Near lake Addie post-office, in section 7, Sumter, where Mr. Newcomb has gathered them for lime-burning, the largest pieces found are three or four feet long; but about a mile distant toward the southeast, in the S. E. $\frac{1}{4}$ of section 18, Sumter, some sixty rods northeast from J. M. Gilhousen's, a slab of buff limestone, at least a dozen feet square, was found lying six inches to two feet below the surface.

The formation of the drift took place in a period of very cold climate by which land-ice was accumulated to a great depth upon this region, as it now exists upon the Antarctic continent and in Greenland. The superficial materials formed by decomposition of the rocks before this glacial period, were then plowed up by the slowly moving ice, mingled with large additions by erosion of the underlying ledges, and carried forward in the direction of the ice-current. Areas of gently undulating contour, like McLeod county, appear to have been covered by ice which moved in a continuous current and disappeared by melting that was extended at the same time over a wide field. The inequalities of surface are very slight in comparison with the thickness of the drift, and the average hight generally rises or falls imperceptibly, its slope being often not more than 50 or 100 feet in as many miles. These general changes in altitude, which affect the whole country and give direction to its drainage, are doubtless produced by differences in hight of the bed-rock upon which the drift lies as a sheet, probably somewhat uniform in depth; but the small elevations and depressions appear to be due to the accumulation of different amounts of till by the shifting action of the moving ice-sheet or by local removal by drainage. This unequal deposition of the drift has produced the multitude of lakes which dot the map of Minnesota. The lapse of time since the ice age has been insufficient for rains and streams to fill these basins with sediment, or to cut outlets low enough to drain them; though in many instances we can see such changes slowly going forward.

Shells and trees found deeply buried between glacial deposits, as in the railroad well at Stewart and in two wells in Hutchinson, particulars of which are given in the following pages, show that this very cold period was not one unbroken reign of ice, but that this retreated and re-advanced, or was possibly at some time nearly all melted and then accumulated anew. Thus periods of ice alternated with interglacial epochs, in which animal and vegetable life spread again northward, following close upon the retreat of the ice-fields. By each new advance of the glacial sheet much of the previous surface would be plowed up and redeposited; hence we find only few and scanty remnants of fossiliferous beds in the glacial drift. At the disappearance of the last ice-sheet these drifted materials, seldom modified by water in their deposition, formed a mantle 100 to 200 feet or more in thickness upon this county and throughout a large portion of the state.

At the departure of the ice, its surface upon large areas was doubtless hollowed into basins of drainage and channeled by streams which flowed between walls of ice. The boulders, gravel, sand and clay, mingled in the ice, mostly in its lower portion, were exposed by this melting, so that at length, when only a small thickness of the ice was left, its surface must have been covered by the drift which it had contained.

Modified drift. From the same ice-held drift came the sand and gravel, or occasionally coarse and only slightly water-worn material, which were deposited in the ridges and knolls called *kames.* These are not so plentiful, nor do they form so well-marked series, in Minnesota as in many other regions. Their outlines are due to deposition from glacial rivers between ice-walls, or among irregular masses of the dissolving ice-sheet. In this county, accumulations which seem to belong to this class were noticed in the west part of section 28, Helen, extending a quarter of a mile along the road from northwest to southeast. They are irregular knolls and short ridges, 10 to 25 feet high, composed in part of very coarse drift, containing a much larger proportion of rock-fragments than the ordinary till, with little evidence of water-wearing. Angular stones of all sizes up to two feet in diameter, are intermingled with gravel and sand, but clay is generally absent. Other portions of these kames are fine gravel and sand, interbedded; and this ordinary modified drift, spread with a gently undulating or nearly level surface, continues a mile or more thence southeastward.

The only other area of modified drift of considerable extent noted in this county is the plain of sand and gravel on which the village of Hutchinson is principally built, situated in the valley of the South branch of Crow river. This deposit reaches a mile or more along this stream from north to south and is about a third of a mile wide. Yellowish sand or fine gravel extends 10 to 25 feet in depth, the lowest two or three feet being often notably streaked with iron-rust. Sometimes a layer of gravel occurs at the bottom, one foot thick, with very abundant pebbles up to eight inches in diameter. Water, usually irony, is frequently found at the base of this modified drift, which is underlain by the impervious till.

Wells in McLeod county.

Records of the material met in digging wells in this county, exhibiting more in detail the character of its drift deposits, are as follows:

Winsted. Michael Krueger; sec. 21: well, 18 feet deep; soil, 2 feet; yellowish till, 4 feet; harder, dark bluish lower till, 12 feet; water comes from a sandy layer twelve feet below the surface.

Bergen. Nils Haldorson; sec. 28: well, 47 feet; yellowish till, 25 feet; bluish till below, 22 feet; water rose from the bottom twenty feet in the first half day, and stands permanently at ten feet below the surface.

Magnus Swenson; sec. 29: well, 18 feet, all yellow till, with dark blue till at the bottom, not dug into; water seeps.

Helen. Fred Walter; sec. 29: well, 40 feet deep; soil, 2 feet; yellowish till, 10 feet; lower till, 28 feet; water rose from the bottom fifteen feet.

The well at the parsonage of the Lutheran church, at the north side of sec. 33, is 20 feet deep, all in sand and fine gravel.

Hale. Basil Jasmer, sec. 28: well, 46 feet; soil, 2 feet; yellowish till, 15 feet; harder gray till, 29 feet; water, found in gravel at the bottom, rose ten feet in a half day.

A. P. Williams; sec. 32: well, 70 feet deep; yellowish upper till, 15 feet; dark bluish till, inclosing pockets of sand, 55 feet; water seeps, standing permanently within ten to fifteen feet below the surface. Most of the wells in this vicinity are dug near sloughs, and are from 10 to 25 feet deep. Bored wells commonly obtain water at depths between 25 and 40 feet.

Glencoe. H. Wadsworth; in village: well dug 60 feet, and bored 20 feet lower; yellowish upper till, about 10 feet; harder, dark bluish till, 70 feet, in which pockets of sand were found at the side of the well at the depths of thirty feet and sixty feet below the surface; no inflow of water from springs, but seeping water fills the well to twenty-five feet below its top. A cistern ten feet distant from this well encountered so much water at eight feet that it could not be bricked up, though no water was found at this depth in the well.

C. Robert Nims; also in the village: well, 19 feet; yellowish till, 12 feet; dark bluish till, 7 feet; water rose from the bottom six feet.

Hutchinson. Andrew Hopper; in village: well, 60 feet; sand and fine gravel, 20 feet; all below is till, excepting a layer of sand reached at the bottom, from which water rose twenty-five feet.

S. Pendergrast; sec. 17, north township: well, 48 feet; yellowish till, 28 feet; dark bluish till, 20 feet, its lowest five feet soft and mucky; water, somewhat disagreeable in taste, seeps from this lower layer, filling the well to a depth of about twenty feet.

Nancy Nutt; southeast corner of sec. 35, north township, about 4½ miles east of Hutchinson village: well, 32 feet deep; yellow upper till, 14 feet; harder gray till, 3 feet; dark bluish till, harder than the upper till, 13 feet; gray sand, dug into only 2 feet, containing abundant gasteropod shells of several species, none preserved, but considered by those digging the well to be identical with the shells found in the lakes of this region; water rose from this sand fifteen feet.

S. D. Ross; northeast corner of sec. 2, south township, ¼ mile east from the last: the well here passed through till to a similar depth with the foregoing, and found likewise a bed of sand at the bottom, containing an abundance of shells and yielding water.

W. Zavoral; N. W. ¼ of sec. 2, south township, less than a mile west from the last: well, 32 feet; yellowish upper till, 15 feet; harder, dark bluish till, 17 feet; water rose from sand at the bottom seven feet in the first hour, and fifteen feet in ten hours.

D. H. Ells; sec. 21, south township: well, 76 feet deep; soil, 2 feet; yellowish till, 12 feet; dark bluish till, harder in its upper part, becoming soft and mucky below, and containing an increased proportion of sand at the bottom, 62 feet; no veins of water were found, but water slowly seeps, filling the well constantly to a depth of fifty feet, even in seasons of drought. Mr. Ells and his son, J. Edwin Ells, have dug many wells in this region, probably more than a hundred, finding in nearly every instance occasional small fragments of lignite, but no fossil shells nor other organic remains. There is almost always found, at the junction or line dividing the upper yellow till from the dark bluish till beneath, a layer of sand, from an eighth of an inch to two inches thick, usually iron-rusted, with a little water. Sometimes a bed, one or two feet thick, of quicksand is found at this line, with much water.

John Moffett; sec. 35, south township: well, 19 feet; yellowish till, 15 feet; harder, bluish gray till, 3 feet; sand, 1 foot, from which water rose four feet in a half hour.

Sumter. E. Rogers; sec. 7: well, 55 feet; yellowish upper till, 12 feet; dark bluish lower till, harder for spading, but easier to bore because it is moister and more tenacious, 43 feet; small pockets of sand, one to four inches thick, were found in the lower till, but no water till the bottom was reached, whence it rose forty feet in one day.

Samuel Leighty; sec. 10: well, 23 feet; soil, 2 feet; yellowish upper till, harder than the next, 4 feet; blue till, 15 feet; gravel, 2 feet, with water, which rose ten feet in one day.

J. Smith; sec. 11: well, 70 feet; yel'ow till, 15 feet; blue till, 55 feet; no water obtained.

Penn. F. L. Groshon; sec. 16: well, 55 feet; yellowish upper till, 12 feet; dark bluish till, 38 feet; coarse blue gravel, same in color as the lower till, 5 feet; a whitish-gray hardpan of sand and clay, very compact, as if cemented, but crumbling on exposure to the air, was found below this gravel, but was only bored into a few inches; water, coming from the gravel, rose to be ten feet deep.

Acoma. Oliver Pierce; sec. 23: well, 20 feet; soil, 2 feet; yellowish till, containing several horizontal streaks of sand, 18 feet; water rose from the bottom four feet.

August Pagel; sec. 27: well, 30 feet; yellowish till, 25 feet; blue till, 5 feet; water plentiful, of excellent quality, as usual throughout this county. Most of the wells in Acoma are 20 to 30 feet deep, the dark bluish till being found at 20 to 25 feet. Small fragments of lignite occur sparingly.

Lynn. John Falconer's well, in the west part of this township, was as follows, having a depth of 38 feet: yellow till, 11 feet; blue till, 24 feet; blue sand, 2 feet, from which water rose twenty feet; hard blue till was found below, the same as above, bored into one foot.

Collins. S. E. Martin; sec. 1: well, 70 feet; yellowish till, 12 feet; blue clay, reported to be stratified and free from pebbles, 12 feet; whitish gray hardpan or till, similar to that found at the bottom of the well mentioned in Penn, 35 feet, this being the greatest thickness of such material found by Mr. L. F. Rogers, who reports this well, in all his experience of boring fully two hundred wells in this and adjoining counties; next beneath was a yellowish gray, clayey quicksand, with much water, 11 feet. At the top of this quicksand a piece of wood, a half inch thick and three inches long, was found. No other organic remains were noticed.

G. A. Hewitt; sec. 12: well only 10 feet deep; yellowish till, 5 feet; gravel, 1 foot; quicksand, 4 feet; water plentiful, on the surface of which, when left undisturbed ten hours, a scum gathers, possessing an odor like kerosene. At a distance of twenty-five feet from this well, Mr. Hewitt bored 90 feet, finding the section as follows: soil, 2 feet; gray and yellowish till, 18 feet; blue till, 70 feet; water rose from sand at the bottom to a permanent level fifteen feet below the surface.

C. A. Carpenter; sec. 15: well, 64 feet; yellow till, 20 feet; harder, blue till, 44 feet, with no sandy veins; no water was obtained in the lower till; but it seeps, during wet seasons, from the base of the yellow till.

James M. Gilhousen; sec. 18: well, 14 feet; soil, 2 feet; yellow till, 8 feet; quicksand, 8 inches, with abundant water; to afford a place to dip the bucket, a depth of three feet was dug into the much harder blue till below, which requires to be picked.

The well for the railroad at Stewart, in section 31 of this township, was bored by C. E. Whelpley of Minneapolis, who reports it as follows: yellowish till, harder to bore than the bluish till below, because it is more stony, 20 feet; dark bluish till, 240 feet; sand, changing downward to coarse gravel, 5 feet, from which water rose 125 feet in three minutes, and soon came to a permanent level only 5 feet below the surface. This water is called soft, and is at least much nearer this condition than that of the surface wells of this region, 20 to 40 feet deep. The trunk of a tree, about one and a half feet in diameter, was encountered in the till in this well, 177 feet from the surface. Shells, supposed to be the same with those now living in the lakes of this region, but of which, unfortunately, no specimens were saved, occurred in a thin muddy layer inclosed in the till about 100 feet below the surface, and again at about 110. Fragments of bones were also noticed in the sand and gravel brought up from the bottom.

MATERIAL RESOURCES.

Agriculture is the chief resource of this district, with its uniformly fertile soil, its many lakes and streams, and its ample supply of timber, all of which have been described in the foregoing pages.

Water powers. Flouring mills run by water-power are located at three places on the South branch of the Crow river, as follows: at Hutchinson, having nine feet head of water; at Koniska, with about seven feet head; and at Saint George, with head of eight feet.

Building stone. The boulders of the drift are the only stone found in this county. These occur in sufficient numbers to be generally used by farmers for cellar-walls and foundations, for curbing wells, and similar purposes. Excellent limestone, adapted for the construction of the most substantial and beautiful buildings, is quarried in the Minnesota and Mississippi valleys, not far to the southeast and east from McLeod county.

Lime. The magnesian limestone boulders, which are found in the drift, have been burned for lime during the past fifteen years or more by J. B. Newcomb, of section 7, Sumter, at Lake Addie post-office. His annual product is only one or two kilns, or from 50 to 150 barrels, being limited by the local demand. This is white lime of the best quality, and is sold at $2 to $2.50 per barrel. It is used mostly for the finishing coat in plastering, or for white-washing. The Shakopee lime, equally strong and durable, but of dark brown color, is brought on the railroad and sold at $1 per barrel.

Basil Jasmer & Son, near Silver lake in the south part of Hale, also burn lime from boulders. Their price at the kiln is $1, and at Hutchinson $1.25 per bushel. Lime has been burned by farmers, for their own use near Saint George, in Rich Valley township.

Bricks. W. H. Wyman has made bricks since 1878 in the southwest quarter of section 20, Hutchinson (north township), about two miles north of the village. In 1879 his product was 100,000, sold at $7.50 to $8 per thousand. These bricks have a light red color. The soil to a depth of six inches is removed, and the stratum occupying the next one and a half feet below, which is a hard, light gray clay, is used for the brick-making, requiring no admixture of sand. This clay continues at least six feet deeper, but in that portion it becomes soft and yellowish, and bricks made from it are cracked by particles of lime. Its first one to two feet below the layer used for the manufacture of bricks is streaked with iron-rust. The locality is a marsh, having only about two acres of the brick-clay.

Attempts to make bricks at other places near Hutchinson village have failed, because of the presence of limy concretions, or fine gravel of limestone, by which the bricks are cracked after burning. This hindrance forbids the manufacture of bricks from the till or boulder-clay, which in many places is sufficiently free from pebbles that it might otherwise be thus used.

ABORIGINAL EARTHWORKS.

Artificial mounds were noted at the northeast side of the lake in the south part of section 29, Glencoe. They are much scattered, probably numbering fifteen or twenty, upon an area of several acres, extending some fifty rods from northwest to southeast. They vary from one to two and a half feet in hight, having the usual dome-like form. One of them, a foot and a half high, was situated in the middle of the road, as it was fenced, when the examination of this county was made, in 1879, and one of the wheel-tracks passed over its edge.

Another group of aboriginal mounds, similar to the foregoing, from one and a half to two feet high, and scattered over a space of ten acres or more, mostly north of the road, was seen in the southeast part of section 34, Hutchinson (north township), about three miles east of the village. These are on the edge of the prairie, and are noticeable from having a thicker and taller growth of grass and other plants than the adjoining areas.

Some thirty or more mounds, also from one to two feet in hight, were seen here and there in and near the road along a distance of three-fourths of a mile in the northeast quarter of section 33, and the west part of section 34, Helen.

CHAPTER VII.

THE GEOLOGY OF RENVILLE COUNTY.

BY WARREN UPHAM.

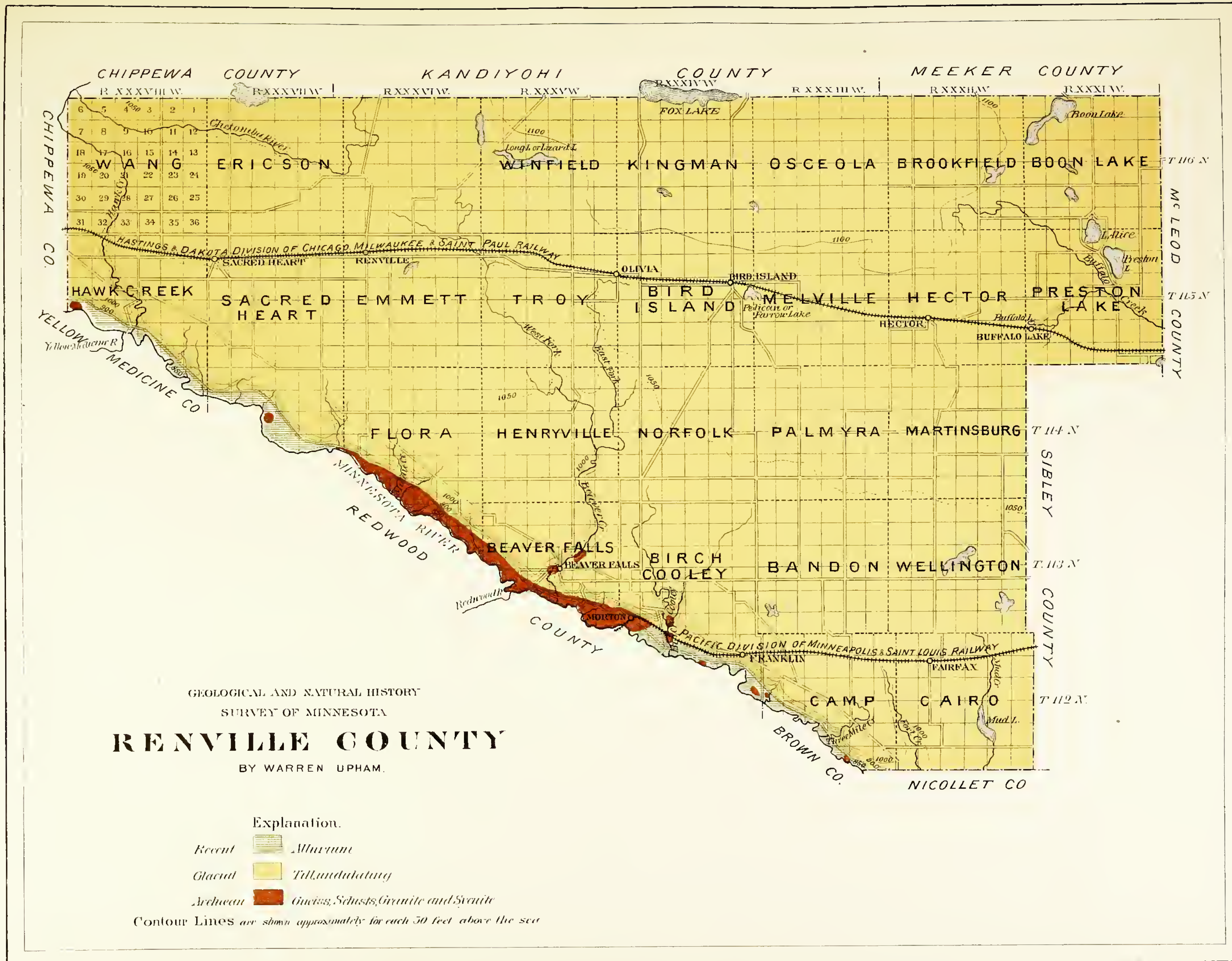
Situation and area. Renville county (plate 38) lies in the central part of the south half of Minnesota. Its southern boundary is the Minnesota river, this county being midway between Big Stone lake and Mankato, the limits of the portion of this river in which it flows southeast. Beaver Falls, the county seat, is about 100 miles west-southwest from Saint Paul and Minneapolis, 75 miles north from the Iowa line, and 70 miles east from Dakota. The Hastings & Dakota division of the Chicago, Milwaukee & Saint Paul railway crosses this county, and at its stations, which in their order from east to west are Hector, Bird Island, Olivia, Renville and Sacred Heart, important villages have sprung up.

The length of Renville county from east to west is 48 miles, and its greatest width is 30 miles. Its area is 981.31 square miles, or 628,036.58 acres, of which 6,385.69 acres are covered by water.

SURFACE FEATURES.

Natural drainage. About three-fourths of this county are drained to the Minnesota river. Beaver creek, some twenty miles long, lying wholly within this county, and Hawk creek, about thirty miles long, rising in Kandiyohi and Chippewa counties, and flowing through the west end of Renville county, are its largest streams tributary to the Minnesota river. Several smaller creeks also join the Minnesota river in this county, including Middle creek in Flora, about three miles long, Birch cooley* in the township to which it gives its

* The term *coulée*, anglicized to *cooley*, meaning a water-course, especially when in a deep ravine, was applied by the French voyageurs to this and many other streams, mostly in the country farther northwest.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
RENVILLE COUNTY
BY WARREN UPHAM.
Explanation.
Recent
Alluvium
Glacial
Till, undulating
Archean
Gneiss, Schists, Granite and Syenite
Contour Lines are shown approximately for each 50 feet above the sea
CHIPPEWA COUNTY
KANDIYOHI COUNTY
MEEKER COUNTY
Mc LEOD COUNTY
SIBLEY COUNTY
NICOLLET CO
BROWN CO.
REDWOOD COUNTY
YELLOW MEDICINE CO
CHIPPEWA CO.
R.XXXVIII.W.
R.XXXVII.W.
R.XXXVI.W.
R.XXXV.W.
R.XXXIV.W.
R.XXXIII.W.
R.XXXII.W.
R.XXXI.W.
T.116.N.
T.115.N.
T.114.N.
T.113.N.
T.112.N.
WANG
ERICSON
WINFIELD
KINGMAN
OSCEOLA
BROOKFIELD
BOON LAKE
HAWK CREEK
SACRED HEART
EMMETT
TROY
BIRD ISLAND
MELVILLE
HECTOR
PRESTON LAKE
FLORA
HENRYVILLE
NORFOLK
PALMYRA
MARTINSBURG
BEAVER FALLS
BIRCH COOLEY
BANDON
WELLINGTON
CAMP
CAIRO
HASTINGS & DAKOTA DIVISION OF CHICAGO MILWAUKEE & SAINT PAUL RAILWAY
PACIFIC DIVISION OF MINNEAPOLIS & SAINT LOUIS RAILWAY
SACRED HEART
RENVILLE
OLIVIA
BIRD ISLAND
HECTOR
BUFFALO LAKE
BEAVER FALLS
MORTON
FRANKLIN
FAIRFAX
FOX LAKE
Boon Lake
Long L. or Lizard L.
L. Allie
Preston L.
Buffalo Creek
Buffalo L.
Pelican or Farrow Lake
Chetomba River
Hawk Cr.
West Fork
East Fork
Beaver Cr.
Yellow Medicine R.
MINNESOTA RIVER
Redwood R.
Mud Cr.
Mud L.
Fort Cr.
Three Mile Cr.
1100
1050
1000
900
850

name, about seven miles long, and Three Mile creek in Camp, about three miles long. From Cairo, the most southeastern township of this county, Fort creek and Mud or Little Rock creek flow southward into Ridgely in Nicollet county.

Nearly one-fourth of Renville county on the northeast is drained to the Mississippi by Buffalo creek and the South branch of the Crow river. The chief sources of Buffalo creek are in the townships of Brookfield, Boon Lake and Preston Lake.

The last two named townships contain several lakes, the largest of which are Boon lake, three miles long from southwest to northeast, lying in the northwest quarter of the township to which it gives its name; Preston lake, one and a half miles long from north to south and nearly a mile wide, in the northeast quarter of Preston Lake township; and lake Alice, close northwest of the last, about a mile long from north to south and three-fourths of a mile wide. Fox lake, four miles long from east to west, lying about half in this county and half in Kandiyohi county, is crossed by the north line of Kingman. Long or Lizard lake, extending three miles from east to west, but narrow, is situated about five miles farther southwest in Winfield. Frequent sloughs, from a few hundred feet to two or three miles long, and occasional small lakes, occur throughout the central and western parts of the county, mostly trending from northwest to southeast, or approximately in this direction. On the southeast, a lake about a mile long lies at the centre of Wellington, and Mud or Little Rock creek flows through another lake of about the same length in the southeast quarter of Cairo.

Topography. Renville county is covered by the glacial drift so deeply that it has no outcrops of the bed-rocks, except in the Minnesota valley, and in the valleys of Beaver creek, Birch cooley and Fort creek, near their junction with the Minnesota. The minor topographic features of this county, excepting within the Minnesota valley, are therefore due to the form in which the surface of the drift-sheet was moulded at the time of its deposition, here a gently undulating broad expanse of nearly uniform average hight, and to the eroding effects of rains, rills and streams since that time, principally exhibited in the excavation of water-courses, varying in size from tiny channels of rivulets to deeper gullies, ravines, and the valleys of rivers. The undulations of the surface rise with long slopes only 5 to 10 or 20 feet above the depressions, and in an extended view these irregularities are merged in the almost level and apparently limitless prairie. The contour of Hector, Melville, Osceola, and the west part of Brookfield, is more undulating or rolling than most other parts of this county. Kame-like hillocks, composed of sand and gravel, were seen near the north line of section 5, Hector, 40 feet above the depression on their north side. East of this tract the contour as usual is nearly level, and Boon lake, lake Alice and Preston lake lie only about fifteen feet below the general surface.

The Minnesota valley cuts this monotonous expanse by bluffs which descend 175 or 200 feet. This valley here varies in width from one to two miles, or rarely three miles as at the south side of Sacred Heart township. Its bottomland contains many outcrops of gneissic rocks, which rise 50 to 100 feet or occasionally 125 feet above the river. The tributaries of this valley also flow in channels which they have eroded to a slight depth along their upper portions, but which increase in depth to their junction with the Minnesota valley, being in the lower part of their course 100 to 150 or 175 feet deep, and an eighth to a quarter of a mile wide. The bluffs of the Minnesota valley are also indented by frequent short cooleys or ravines, eroded by the rivulets which flow in them, issuing from perennial springs, or in many instances kept running only through the more wet portions of the year. Scarcely a half mile of the bluff can be found without such indentations. The length of these ravines is usually only a few hundred yards, but some are a half mile or a mile long, and then their supply of water, being from deep springs, is less affected by droughts than the larger streams.

Elevations, Hastings & Dakota division, Chicago, Milwaukee & Saint Paul railway.

From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from Hastings.	Feet above the sea.
Depression, in the east edge of Renville county, grade,	92.2	1057
Summit grade,	93.1	1076
Near McLaughlin's lake, grade,	94.6	1064
Outlet of a lake, bottom, 1060; grade,	96.1	1066
Summit, highest between Hastings and Ortonville, grade,	100.3	1093
South fork of Buffalo creek, water, 1067; grade,	101.4	1082
Hector,	102.4	1081
Bird Island (nearly level from last station to here),	111.6	1089
Olivia,	116.0	1082
East fork of Beaver creek, water, 1066; grade,	116.5	1073
West fork of Beaver creek, water, 1051; grade,	123.7	1057
Renville,	127.2	1064
Sacred Heart,	134.1	1061
Hawk creek, water, 963; grade,	139.3	1017
Natural surface 500 feet farther west,	139.4	1041
Line between Renville and Chippewa counties, grade,	140.7	1047

Elevations, Pacific division, Minneapolis & Saint Louis railway.

From profiles in the office of Robert Angst, engineer, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
Line between Sibley and Renville counties, grade,	82.2	1046
Mud or Little Rock creek, water, 1022; grade,	84.1	1038
Fairfax,	86.9	1041
Fort creek, water, 1013; grade,	89.5	1020
Three Mile creek, water, 1015; grade,	90.3	1024
Franklin,	94.9	1005
Birch cooley, water, 832; grade,	98.8	837

Morton,	100.4	841
Minnesota river, low and high water, 814 to 836; grade,	100.7	840

The elevation of the Minnesota river along the southwest side of this county, at its ordinary stage of low water, 20 to 25 feet below its highest floods, is approximately as follows:

Minnesota river, low water.

	Feet above the sea.
At the west line of Renville county,	852
Mouth of Hawk creek and of Yellow Medicine river,	848
At the west line of Sacred Heart and of Redwood county,	845
Mouth of Middle creek, below Patterson's rapids,	825
Mouth of Redwood river,	818
Mouth of Beaver creek,	816
At Morton,	814
Mouth of Birch cooley,	811
At east line of Birch cooley and of Redwood county,	803
At line between Renville and Nicollet counties,	796

The highest land of Renville county is in its northern part, from Hector and Brookfield westward to Lizard lake, the swells of the undulating prairie there being 1,100 to 1,125 feet above the sea, while the depressions containing sloughs or lakes are mostly below 1,100. The valley of the Minnesota river where it leaves the county is its lowest land, being 796 feet above the sea; but its bluffs, rising 200 feet, have their tops only about a hundred feet lower than the highest part of the county twenty-five to thirty miles farther north.

Estimates of the average hight of the townships are as follows: Boon Lake, 1,085 feet above the sea; Preston Lake, 1,075; Brookfield, 1,100; Hector, 1,090; Martinsburg, 1,065; Wellington, 1,040; Cairo, 1,015; Osceola, 1,110; Melville, 1,090; Palmyra, 1,060; Bandon, 1,035; Camp, 1,000; Kingman, 1,110; Bird Island, 1,080; Norfolk, 1,045; Birch Cooley, 1,000; Winfield, 1,090; Troy, 1,065; Henryville, 1,030; Beaver Falls, 990; T. 116, R. 36, 1,075; Emmett, 1,060; Flora, 1,000; Erickson, 1,060; Sacred Heart, 1,030; Wang, 1,040; and Hawk Creek, 1,010. The mean elevation of Renville county, derived from these figures, is 1,055 feet.

Soil and timber. The black soil is from one to one and a half feet deep, and gradually changes in the next foot to the yellowish color which characterizes the drift near the surface. In sloughs and on the bottomland of the Minnesota river, however, the thickness of the fertile black soil is often from two to four feet. Wheat-raising has been the chief agricultural resource of this region, but a great variety of farm crops can be successfully raised, including all that are produced in this latitude in states farther east.

Nearly all of Renville county is prairie, or natural mowing-land and pasture, needing only plowing and seeding to prepare it for harvest. Timber occurs along the bluff of the Minnesota river, and in a narrow belt along the river's course, but most of the bottomland is treeless. The valleys of Hawk and Beaver creeks, Birch cooley, and the small creeks in Camp and Cairo, are also wooded; and groves are found on the borders of Boon lake, lake Alice, and Preston lake.

Birch cooley takes its name from the paper or canoe birch (*Betula papyrifera*, Marshall), which occurs plentifully on this creek, some of its trees attaining a diameter of one foot, in sections 28 and 33 of Birch Cooley township. It is also found, but only sparingly, on Beaver creek, and on Wabashaw creek in Redwood county; while farther southwestward in the state it is absent. Other species of trees in this county include basswood, sugar maple and white or soft maple, box-elder, wild plum, white and green ash, white and red or slippery elm, hackberry, bur oak, ironwood, poplar, cottonwood, and red cedar.

GEOLOGICAL STRUCTURE.

Archæan rocks. The Minnesota valley on the boundary of Renville county, excepting south of Hawk Creek township, contains frequent or in most portions abundant ledges of gneiss and granite, in some places inclosing masses of hornblende schist. For twelve miles above Beaver Falls, to the west line of Flora, these rock-outcrops fill the whole valley, occurring on each side of the river, and rising 50 to 125 feet above it. Between Beaver creek and Birch cooley the outcrops are mainly on the north side of the Minnesota, rising in their highest portions 100 feet above the river. 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.

Near the east line of section 20, Beaver Falls, a quarter of a mile north from the ford of the Minnesota river, the rock is gray gneiss, weathering to reddish gray, apparently almost vertical, with its strike E. N. E. At the east side of the road this gneiss is crossed by a nearly vertical vein, one to three feet wide, of coarsely crystalline feldspar and quartz, extending within sight 50 feet. These strata are also exposed in the valley of Beaver creek one and two miles above its junction with the Minnesota valley. The Champion mill-dam at the village of Beaver Falls is nearly within the line of strike of the gneiss described north of the ford, and a similar gneiss, with nearly the same strike, is found here. Its dip is 15° S. S. E. At the dam of the O K mill, one mile northeast from the last, is an extensive exposure of gray gneiss, also with E. N. E. strike; it is nearly vertical or has a steep dip to the S. S. E., and in some portions is much contorted. Veins, six to eighteen inches wide, of coarsely crystalline flesh-colored feldspar, coinciding with the strike, are common here.

In the valley of Birch cooley, about one mile above its entrance into that of the Minnesota, and within an eighth of a mile above Bartley & Alexander's woolen mill, are large exposures of granite, holding interesting veins, faulted and divided portions of which were figured and described by Prof. Winchell in the second annual report. One of these veins, composed of granite and four inches wide, is traceable 250 feet, running southwest. Other extensive outcrops of granite or gneiss, partly decomposed, apparently dipping S., S. E. and S. W., form the sides of this valley or ravine below the mill.

Two miles southeast from the mouth of Birch cooley, a low outcrop examined on the north side of the river is granitoid gneiss, containing a large proportion of flesh-colored feldspar. This is in the N. W. ¼ of section 10, Birch Cooley, near where Mr. William H. Post formerly lived. At an excavation for building a house near by, in the S. W. ¼ of section 3, a bed of decomposed gneiss was noted, showing a dip of 20° to the W. N. W. Ledges were next seen on the north side of the river three miles below the last, in the vicinity of the line between Birch Cooley and Camp, extending a half mile westward from Reike & Fenske's flour mill, and rising 10 to 25 feet above the bottomland. Another small outcrop, the most southeastern observed in this county, occurs about five miles farther southeast, being on the north side of a small round lakelet in the bottomland, probably in the east part of section 34, Camp.

The most northwestern exposure of rock noted in Renville county is in the N. E. ¼ of section 16, Sacred Heart, where a ledge of gneiss rises about 50 feet above the river. One to three miles farther west, but on the south side of the river, it has more prominent and extensive outcrops. In the next six or seven miles northwestward to the west line of this county, no rock-exposures were found.

Archæan gneiss and related crystalline rocks doubtless also underlie the drift upon this entire county, being continuous from the Minnesota river northeast to the syenite, granite and gneiss exposed in Stearns, Benton and Morrison counties and in the north part of the state.

Decomposed gneiss and granite. In the portion of the Minnesota valley adjoining this county, the outcrops of gneiss and granite are frequently found to be more or less decomposed, being changed in their upper part to a soft, earthy or clayey mass, resembling kaolin. This condition of the rock, as observed by Prof. Winchell in its exposures on Birch cooley, has been described by him as follows.*

"A substance was met with here for the first time which was afterwards seen at a number of places. Its origin seems to be dependent on the granite. Its association with the granite is so close that it seems to be a result of a change in the granite itself. It lies first under the drift, or under the Cretaceous rocks, where they overlie the granite, and passes by slow changes into the granite. It has some of the characters of steatite, and some of those of kaolin. In some places it seems to be a trne kaoliu. It is known by the people as 'Castile soap.' It cuts like soap, has a blue color when fresh, or kept wet, but a faded and yellowish ash color when weathered, and when long and perfectly weathered, is white and glistening. The boys cut it into the shapes of pipes and various toys. It appears like the pipestone, though less heavy and less hard, and has a very different color. It is said to harden by heating. This substance, which may, at least provisionally, be denominated a *kaolin*, seems to be the result of the action of water on the underlying granite. Since it prevails in the Cretaceous areas, and is always present, so far as known, whenever the Cretaceous deposits have preserved it from disruption by the glacier period, it may be attributed to the action of the Cretaceous ocean. In some places it is gritty, and in others it may be completely pulverized in the fingers. A great abundance of this material exists in the banks of the Birch cooley, within a short distance of its mouth."

Samples of this substance were analyzed by Prof. S. F. Peckham, who reported it as follows:† "A dull-green, amorphous mineral, unctuous and soapy to the touch. Fracture uneven, coarsely granular. Hardness, 1.5. Easily cut with a knife, giving a smooth surface. Specific gravity, 2.562. Lustre dull, waxy, with very minute pearly scales. Color mottled, dull-green to grayish-green, opaque, scales translucent. When wetted it absorbs water and softens, bnt does not become plastic. In closed tube it gives water. B. B. infusible. Gives the color with cobalt, which is indistinct from excess of iron. Is decomposed by hydrochloric acid, leaving a white insoluble residue containing only a trace of iron. The oxidation of the iron varies according to the extent of the exposure. The following are the mean results of three closely concordant analyses: silica, 37.88 per cent.; ferric oxide, 15.78; alumina, 26.96; magnesia, I.74; potash and soda, 0.95; water, 15.88. A trace of lime was uot determined. These results show the mineral to be allied to Fahlunite, var. Hurouite of T. S. Hunt. See Dana's *Mineralogy*, ed. 1870, p. 485."

Many exposures of this decayed gneiss and granite were observed in the ravines of creeks and in excavations for roads along the lower portion of the Minnesota valley bluffs through Camp, Birch Cooley, Beaver Falls and Flora. In the west part of section 21, Beaver Falls, near the foot of the descent to Redwood Falls ferry, decomposed gneiss is seen in the gutter at the east side of the road along a distance of about thirty rods, declining in hight from 60 to 30 feet above the river. The depth to which the decomposition extends in this locality is at least ten feet. The decayed rock here is cream-colored or nearly white. It is generally gritty with particles of quartz distributed

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* Second annual report, p. 163.

† Fifth annual report, p. 60.

through its mass, and also contains veins of quartz one to two inches thick, and of feldspar (kaolinized) one foot thick.

Cretaceous beds are found in many places along the Minnesota valley, lying on the Archæan rocks and separating them from the glacial drift. Before the ice age Cretaceous deposits probably constituted the surface generally throughout western Minnesota, but they were in large part eroded by the ice, supplying much of its drift, beneath which their remnants are now concealed, excepting where they have become exposed to view in deeply excavated valleys.

On Fort creek in section 31, Cairo, and in the adjoining edge of Nicollet county, beds of Cretaceous clay or shale occur, containing in one place a thin layer of limestone and at another point a seam of clayey lignite, or brown coal, about one and a half feet thick. More full notes of these outcrops have been given in the chapter describing Sibley and Nicollet counties. Three miles west from Fort creek, a bed of grayish white Cretaceous clay, levelly stratified, was seen to a thickness of seven feet in an excavation on the upper side of the river road, near the foot of the bluff, in the north edge of the N. E. ¼ of section 34, Camp, half a mile east from Pless' mill and at a hight of about 40 feet above the river. Close west from this point, another excavation beside the road was in decomposed gneiss or granite, this being my most southeastern observation of such decay of the Archæan rocks. At Redwood Falls and within a few miles to the southeast, nearly opposite Beaver Falls, layers of Cretaceous lignite have been explored in the bluffs of the Redwood and Minnesota rivers (vol. I, page 577), without finding any deposit of lignite sufficiently thick to be profitably worked, and it seems very unlikely that such will be discovered in this state.

Most of the observations of Cretaceous strata along this portion of the Minnesota valley have been in its southwestern bluffs and on its southern tributaries. Besides the localities on Fort creek and in Camp township, the only further notes of Cretaceous outcrops in Renville county are the following, recorded by Prof. Winchell in the second annual report.

"At a point two miles below the Lower Sioux Agency, sec. 10, T. 112, R. 34 [in Birch Cooley], on the north side of the Minnesota, a small creek joins the river. Up this creek, about three-quarters of a mile from the river bluffs, the Cretaceous appears in its banks. A concretionary marl, or apparently limy earth, of a white color, crumbles out under the projecting turf. It appears in fragments of an inch or two, or sometimes larger, with angular outline. The surfaces of these pieces show a great number of round or oval spots, or rings, which seem to be formed by the sections of concretions inclosed in the mass. It is rather hard when dry, and nearly white. It is associated with a blue clay, the relations of which cannot here be made out.

"At a point a little further up this creek appears a heavy deposit of concretionary, rusty marl . . in heavy beds that fall off in large fragments, like rock. The first impression is that the bluff is composed of ferruginous conglomerate, but there is not a foreign pebble in it. Every little round mass has a thin shell which is easily broken, revealing either a cavity or a loose, dry earth. These concretions are generally not more than ¼ or ½ inch in diameter; seen 18 feet. Under this is the light, concretionary clay or marl already described."

Glacial and modified drift. Glacial striæ were seen in several places on the ledges of gneiss at the dam of the O K mill, Beaver Falls, bearing S. 60° E., referred to the true meridian; and again in the N. W. ¼ of section 10, Birch Cooley, having the same direction.

The unmodified glacial drift, or till, with comparatively small associated deposits of modified drift, covers this county to an average depth of about a hundred and fifty feet, as shown in the Minnesota valley, where it has been cut through by fluvial erosion. The till here has the yellowish color near the surface, due to weathering, and the dark and bluish color below, which it possesses generally throughout the western two-thirds of this state.

Red till, having the same color with that which is spread over northeastern Minnesota, was observed at only one locality in Renville county. This was at the northeast corner of Reike & Fenske's mill in section 18, Camp, where a section, exposed three rods in length and twelve feet in hight, consisted wholly of this red till, excepting two or three feet of soil and gray till on the surface. It is in the lower part of the Minnesota valley bluff, about 50 feet above the river. Several other such exceptional deposits of red till in the great area of blue till covering western Minnesota and eastern Dakota are noted in volume I, page 628, where their origin is attributed to an ice-current reaching southwestward from lake Superior across Minnesota in the early glacial epoch when the ice attained its maximum extent and depth. Another explanation of the red color of the till in these isolated localities is suggested by Prof. Winchell, who thinks that it may have been caused by the glacial erosion of red shales and sandstones lying near on the north, coloring the drift locally in the same way as it was colored over a large area by derivation from such rocks about lake Superior. As this part of Minnesota is almost universally drift-covered, the underlying rock-formations are only partially known. No decisive evidence for this view is found, but much probability is given to it by the occurrence of red shales in the deep well at Mankato and of red quartzyte in Nicollet, Cottonwood, Pipestone and Rock counties, similar to the lake Superior rocks and belonging with them to the same Potsdam period.

Boulders are only sparingly present in the till of this region, excepting on the bluffs of the Minnesota valley and its larger tributaries, where they seem to have been left in the process of erosion, and also at a few localities in the west part of the county, where they occasionally occur in remarkable abundance along the course of slight depressions on the general surface of the drift-sheet. In the Minnesota valley boulders were seen especially plentiful on the bluffs through Birch Cooley township; and in the valley of Hawk creek they abound on its east bluff within a quarter of a mile south from the bridge in the N. E. ¼ of section 17, Hawk Creek. Many boulders were noted in a depression extending from north to south, about 30 feet deep and a sixth of a mile wide, crossed by the highway and railroad near the middle of sections 1 and 12, Sacred Heart; also in similar north-to-south hollows, about 10 feet below the average level, a third of a mile and again about one mile west of Olivia. These depressions were probably water-courses during the departure of the ice-sheet, and their boulders may belong to the stratum of rocky drift, apparently a buried moraine, which is observable along the Minnesota valley and within a few miles north from it through Chippewa, Swift and Big Stone counties. The size of these rock-fragments seldom exceeds five feet. Most of them are granite, syenite, and gneiss; several of hornblende schist were observed in sections 1 and 12, Sacred Heart, but elsewhere few or none of this rock are found; magnesian limestone, which is everywhere present, making about half of the gravel in the drift, usually supplies a small proportion, perhaps one in twenty, of the large boulders, and even occurs rarely in blocks or slabs ten feet or more in extent.

An interglacial forest-bed is inclosed in the drift upon a considerable area near the centre of this county. At Olivia station, in section 7, Bird Island, the well at Lincoln Brothers' mill was yellow till, picked, 10 feet; softer but more rocky blue till, 9 feet; very hard blue till, 1 foot; and quicksand, 4 feet. A log, apparently tamarack, eight inches in diameter, with several smaller sticks and twigs, lay across this well, imbedded in the top of the quicksand. They were chopped off at each side. G. W. Burch, two miles southwest from this, in section 24, Troy, found yellow till, 18 feet; dry, yellow sand, 4 feet; soft blue till, 15 feet; black loam, perhaps an interglacial soil, 2 feet; and gray quicksand, 4 feet, its upper part containing a log and smaller sticks like the foregoing. Several other wells within one or two miles about Olivia show similar remains of a deeply buried forest-bed, overlain by till.

Terraces apparently formed in the till of the general drift-sheet were observed at two places on the Minnesota valley bluffs, one being in section 21, Hawk Creek, lying about 40 feet below the top of the bluff and extending nearly a mile between the creek and the river, and the other in Beaver Falls, lying 20 to 40 feet below the top of the bluff, from an eighth to a quarter of a mile wide and extending two miles, with a slight descent from northwest to southeast. These terraces are quite noticeable from the opposite side of the river. Seen from that distance, they show flat outlines, contrasting with the somewhat undulating higher land.

Kame-like mounds and small short ridges of gravel and sand, extending ten or twenty rods and rising 15 to 25 feet above the general level, are scattered over most portions of this and adjoining counties. These small deposits of modified drift lie on a surface of till, and are attributable to the action of streams produced in the final melting of the ice-sheet. Occasionally such a gravel knoll is quite isolated, distant a half mile or more from any other. They are sometimes coarse gravel, with pebbles or rounded stones up to a foot or more in diameter; again they are fine gravel and sand, interstratified and obliquely bedded. When they form short ridges, their trend in the central and west parts of this county is prevailingly from northwest to southeast, and from west to east in its east part, but they are mostly only twice or three times as long as they are wide, and no distinct series was noticed. In Brookfield, Osceola, Hector, Melville, Bird Island, and Birch Cooley, numerous mounds of this kind were observed. An excavation to the depth of seven feet in one which is nearly round and 20 feet high, situated in or near the S. W. ¼ of section 2, Bird Island, shows it to consist of gravel and sand irregularly interbedded in layers 3 to 8 inches thick. Its pebbles, more than half of which are limestone, are mostly less than two inches in diameter, but rarely as large as six inches.

Modified drift occurs also within the sheet of glacial drift, forming the thin layers or seams of water-bearing gravel and sand so often struck in well-digging, and occasionally beds of considerable thickness. A section extending vertically 40 feet in modified drift that seems to be a part of the drift-sheet, being probably overlain by till, was observed in section 27, Camp, at the east end of Pless' mill-dam on Three Mile creek where it enters the Minnesota valley. In descending order, this was coarse gravel, 4 feet, containing pebbles up to about one foot in diameter; gravelly sand, 5 feet; coarse gravel, cemented by iron-rust (limonite), 3 feet; and obliquely stratified sand and fine gravel, about 30 feet.

No terraces of modified drift were found in the part of the Minnesota valley bordering this county.

A fossiliferous layer of postglacial gravel lies in the east bank of Hawk creek in the S. E. ¼ of section 8, Hawk Creek township, three to fifteen rods north from the highway bridge. The valley of the creek is here about 75 feet deep, inclosed by bluffs of till. In its bottom a terrace of gravel and sand, about twenty rods wide, borders the stream, above which its hight is 15 feet. On the slope from this terrace to the creek the outcropping edge of a layer of fine gravel about two feet thick, 6 to 8 feet above the water, differs from the bank above and below by being cemented with calcareous matter, and in this bed many shells are found. These have been kindly determined by Mr. R. Ellsworth Call, as follows: *Sphærium striatinum*, Lam., *Valvata tricarinata*, Say, *Amnicola limosa*, Say, *Gyraulus parvus*, Say, a *Goniobasis*, probably *G. livescens*, Menke, and representatives of the genera *Unio*, *Anodonta* and *Campeloma*. Mr. Call states that all these species are found living in this region, and that the four named with certainty are also common in the loess of Iowa.

Wells in Renville county.

Boon Lake. W. S. Pierce; sec. 30: well, 21 feet deep, situated on a little swell, all sand to the bottom, where a good supply of water is found. Another well in the same section, a quarter of a mile farther southwest, is 32 feet deep, in soil, 2 feet; yellow till, spaded, 22; and dark bluish till, harder, 8; water rose slowly six feet from a gravelly vein.

C. D. McEwen, sec. 31: well, 32 feet; soil, 2; yellow till, 10; harder blue till, 20; water rose from gravel at the bottom to four feet below the surface, and stands permanently at this hight, which is three feet above a creek about fifty feet distant.

Preston Lake. H. H. Davis; sec. 7: well, 50 feet; soil, 2; yellow till, 12; blue till, nearly like the yellow in hardness, 36 feet, containing occasional thin sandy seams from which water seeps scantily; gravel was found at the bottom, from which water rose twenty-eight feet in one day. Small fragments of lignite are found frequently in the till; but no wood, nor any evidence of interglacial beds, was learned of in this part of the county.

Brookfield. Alexander Camp; sec. 26: well, 15 feet; soil, 2; yellow till, 13, not dug through; water comes in from a sandy streak all around the well six feet below the top, and also seeps from the till below; it stands permanently eight feet deep.

Bartimeus Case; sec. 34: well, 39 feet, described as clayey sand, 10 feet; hard clay, 5 feet; and soft clayey sand, 24 feet; perhaps all till, as no portion caved in while being dug; water at bottom a large supply, but not rising.

Hector. Samuel Leighty; sec. 6: well, 13 feet, all sand; water two feet deep, coming in so large supply that it cannot be exhausted by pumping.

J. G. Torbert; sec. 6: well, 30 feet: soil, 2; yellow till, spaded, 8; very hard blue till, 5; dark bluish clayey sand, soft and caving in, containing occasional boulders, 15 feet; water seeps, becoming two feet deep. This is only twenty rods west of Mr. Leighty's well, both being at the same hight, which is about 12 feet above a slough forty rods farther north.

Reuben Nightingale; sec. 8: well, 35 feet; soil, 2; yellow till, 10; harder blue till, 10, hardest in its lower part; and soft clayey sand, dark bluish, caving in, containing stones up to one foot in diameter, apparently a variety of till, 13 feet; water comes in small amount, almost failing in dry seasons.

At Hector village, in the N. E. ¼ of sec. 29, wells find the upper yellow till usually 10 to 20 feet deep, succeeded by blue till in which veins of gravel or sand are found in most cases within 20 or 30 feet below the surface, with water rising from them ten or fifteen feet. The town well, 60 feet deep, was yellow till, spaded but very hard, 40 feet, extending deeper in this well and that of the elevator near it on the west than in any other wells of the village; blue till, 20 feet; and gravel at the bottom, from which water rose immediately twelve feet and soon came to its permanent level twenty feet below the surface. M. Abbott's well, 24 feet deep, was yellow till, 10 feet; yellow sand, 3 feet, with water; and blue till, not dug through to any deeper water-bearing vein, 11 feet. Theodore Miller's well, close southwest of the village, 32 feet deep, was soil, 2 feet; hard yellow till, picked, 15 feet; and blue till, soft and moist, spaded, 15 feet; water rises twenty-two feet from the bottom.

Wellington. William Carson; sec. 22: well, 37 feet; yellow upper till, 15 feet; quicksand, 2 feet; blue lower till, very hard, 20 feet; water seeps from the upper till and quicksand; no additional supply was obtained in the lower till.

Cairo. Edmund O'Hara; sec. 8: well, 15 feet, all yellow till; water seeps.

Walter Knapp; sec 18: well, 30 feet, all in yellow till, containing in some portions whitish streaks of calcareous matter.

Melville. George H. Megquier; sec. 6: well, 32 feet; soil, 2; yellow till, 12; blue till, 5; quicksand, 4; and blue till again, 9; the auger then dropped about a foot, and water rose fifteen feet, bringing up sand with it.

N. G. Poor; sec. 18: well, 31 feet; yellow till, 15; blue till, softer to bore, 16; the auger then fell six inches, and water rose fifteen feet in a quarter of an hour. The lower blue till is reported to be usually softer than the yellow in this vicinity.

Palmyra. Ole Halvorson; sec. 30: well, 22 feet; soil, 2; yellow till, spaded but hard, 18; and soft blue till, 2 feet; water seeps in small amount. Another well on the same farm is 32 feet deep, being yellow till, 20 feet; soft blue till, 10; and dark gray sand, 1½ feet, with fine yellow clay below; water rises from the sand three feet.

Bandon. James Hurley; sec. 7: well at house, 21 feet; soil, 2; upper yellow till, 6; intermixed yellow and blue till, 13; water seeps, standing six feet deep in dry seasons. Well at stable, 28 feet; soil, 2; yellow till, 4; harder blue till, 22; no veins of water or sand; water seeps, keeping a permanent depth of ten feet.

Bird Island. The railroad well at Bird Island station, 74 feet deep, was dug 35 feet, in soil, 2 feet; yellow till, 13; blue till, 10; and caving sand and gravel, 10 feet and continuing lower, with much water, not considered, however, a sufficient supply; this well was bored 39 feet lower, but the section of this portion was not learned; water rose in one hour from gravel at the bottom to the level which it holds permanently, ten feet below the surface.

L. E. Sherwood's well, also in Bird Island village, 37 feet deep, was yellow till, 20; blue till, harder, 3; and yellow and blue till intermixed, more sandy than the preceding, 4 feet; water rose from the bottom twenty-seven feet in one day. Most of the wells here are only 25 to 30 feet deep, going through 12 to 20 feet of yellow till, which is usually hard, requiring to be picked; then blue till, commonly softer than the yellow, reaching to 25 or 30 feet below the surface, its lowest two feet being harder; and under this, in nearly all cases, gravelly sand is found, with water rising from it ten or fifteen feet.

In Lincoln Brothers' well at Olivia, which encountered an interglacial forest-bed as already described, water rose ten feet from the quicksand in half a day.

Birch Cooley. Patrick Foley; N. E. ¼ of sec. 22: well, 30 feet; soil, 2; yellow till, 20; softer blue till, 8; water rose four feet from gravel at the bottom.

W. H. Jewell; S. W. ¼ of sec. 22: well, 32 feet; soil, 1½ feet; yellow till, 27 feet; gravel 6 inches, with water rising two feet above this vein; and again yellow till below, dug into three feet. The till of this well was all hard below the first five feet, requiring to be picked.

Troy. Mr. Burch's well, before described because of its interglacial forest-bed, obtained a depth of fifteen feet of water from the quicksand at the bottom.

Henryville. E. E. Comstock; sec. 32: well, 25 feet; soil, 2; hard yellow till, requiring to be picked, 15; harder blue till, 8; from gravel at the bottom, water rose eleven feet in three hours.

Beaver Falls. Caleb Rich; sec. 8: well, 12 feet, situated on a kame-like knoll; soil and gray clay, 7 feet; and gravel and sand, 5 feet, to water in quicksand.

R. R. Corey; also in sec. 8: well bored 95 feet, obtaining no water; soil, 2; yellow till, 30; harder blue till, 40; interstratified clay and sand, 10; and sand and fine gravel, 13. A similar section was found by another well, 85 feet deep, about fifty rods farther east. This went ten feet into the same stratified beds as the preceding, and the bottom of each was dry sand and fine gravel. A. D. Corey's well, in the same section, a quarter of a mile southeast from these, 55 feet deep, was soil, 2; yellow till, about 25; softer blue till, also about 25, becoming more sandy below; and sand and gravel, 3 feet, from which water rose eight feet.

Emmett. The deepest well in this county is that bored for the railroad water-tank at Renville station, in section 5 of this township. Its depth is 201 feet, going through yellow till, 32 feet; and harder blue till, 168 feet; to gravel and sand, from which water rose quickly to its permanent level ten feet below the surface. Stevens & Griffin's elevator at this station has a well 44 feet deep, through soil, 2 feet; yellow till, picked, 15 feet; and harder blue till, 27 feet; water rises from the bottom sixteen feet.

Flora. Fred Haubrech; sec. 26: well, 23 feet; soil, 2; yellow till, 18; yellow sand, 6 inches; very hard blue till, 3 feet, "almost as hard as stone;" with sand and fine gravel below, from which water rose six feet in a half day.

John Foster; sec. 27: well, 28 feet; soil, 2; yellow till, spaded, 10; blue till, much harder, picked, 16; to sand, not dug into, with water rising from it five feet.

Sacred Heart. The following three are in the village at the railway station, in sec. 7. C. H. Lang & Co.'s warehouse: well, 95 feet; soil, 2; yellow till, spaded, 28; harder blue till, picked, 65; only seeping water is found. H. O. Field: well, 52 feet; soil, 2; yellow till, spaded, 22; sand and gravel, 2; and very hard blue till, 26; water rose from the bottom twenty-four feet. F. H. Wolstad: well, 41 feet; soil, 2; yellow till, hard, but spaded, 24; and harder blue till, 15; water rose slowly from the bottom, becoming twenty feet deep.

Martin Frederickson; N. E. ¼ of sec. 10: well, 37 feet; soil, 2; yellow till, hard, mostly picked, 16; softer blue till, 19; no layers nor veins of sand, and no water.

Hawk Creek. Ole Deason; N. W. ¼ of sec. 16: well, 30 feet, seen unfinished, before reaching water; soil, 2; yellow till, 10; gravel and sand, 1½ feet; and again yellow till, spaded but hard, 16 feet.

MATERIAL RESOURCES.

The chief occupation and source of wealth of this county is agriculture, and its capabilities in this direction have been noted in an earlier part of this chapter.

Water-powers are utilized as follows:

Champion mills (flour and lumber), on Beaver creek at Beaver Falls; head, eighteen feet.

O K flour mill, on the same creek one mile above Beaver Falls; head, twenty-eight feet.

Bartley & Alexander's woolen mill, on Birch cooley in section 33, Birch Cooley township; head, fifteen feet.

Reike & Fenske's flour mill, in the N. W. ¼ of section 18, Camp, on a stream that has its source in springs only a half mile from this mill; overshot wheel; head, forty feet.

Marschner's woolen mill, close below the last, on the same stream; head, sixteen feet.

Pless' flour mill, on Three Mile creek in section 27, Camp; head, twenty feet.

Building stone has not yet been quarried, at least in any noteworthy amount, from the rock-outcrops in this county. These have mainly too contorted or irregular foliation and too variable texture to be adapted for this use; but probably some portions of them could be profitably worked. On farms the scanty boulders of the drift have been generally gathered in sufficient amount for building purposes.

Lime. Boulders of magnesian limestone are burned for lime by John Edget, in the southwest part of Birch Cooley township; R. R. Corey, in section 8, Beaver Falls; and Ole Deason, in section 16, Hawk Creek; averaging 50 to 100 barrels yearly, and selling at $1.50 per barrel. This lime is white, and of the best quality. A small portion of the limestone boulders, perhaps one in twenty, is rejected, as they would produce yellowish lime. The largest limestone blocks ordinarily found are four to six feet long, but occasionally they measure twice that size. Mr. Corey reports one 12 by 8 by 4 feet in dimensions. Others equally large are found just beneath the soil in section 2, Bird Island, on land of John Engstrom and of Clara Bowler; and several such are said to occur within a space twenty rods across in the southwest part of section 6, Melville.

A deposit of travertine, or "petrified moss," was shown to me by Mr. Ole Deason, situated on the south side of a wooded ravine 60 feet deep, in the N. W. ¼ of section 22, Hawk Creek. It has a light gray color, and is more compact than usual, but encloses impressions and casts of leaves and twigs. Two exposures of it were seen about four rods apart, each showing a thickness of 6 or 8 feet.

Bricks were made several years ago by William Manke in the northwest part of Wellington, and by Ole Olson a half mile west of Beaver Falls. In the first case the product was small, to supply the local demand in building; and in the second the work was unsuccessful. At the time of collecting these notes, in 1879, no brick-making was being done in this county.

Minerals. Mr. M. Abbott, of Hector, showed me a portion, which had come into his possession, of a singularly beautiful mass of amethyst crystals, found about a foot below the surface a few rods south of the elevator at Hector station. The entire mass was about twelve inches long and four inches wide, attached to a layer of nearly black rock, about a quarter of an inch thick, in which are frequent minute crystals of pyrite. From this base the amethyst crystals rise three and a half inches, and the largest have a diameter of two inches. Some of these large crystals contain in the faces of their terminal pyramids particles and irregular crystals of pyrite, up to an eighth of an inch wide and a third of an inch long. Mr. Abbott thinks that this mass was brought by Indians or by the early French voyageurs. It exhibits no marks of glacial wearing.


STEVENS COUNTY
POPE COUNTY
BIG STONE COUNTY
KANDIYOHI COUNTY
LAC QUI PARLE COUNTY
YELLOW MEDICINE COUNTY
RENVILLE COUNTY
SWIFT
CHIPPEWA
HEGBERT
FAIRFIELD
TARA
CLONTARF
BENSON
CAMP LAKE
KERKHOVEN
SHIBLE
MOYER
MARYSLAND
SIX MILE GROVE
TORNING
KILDARE
HAYES
APPLETON
NEW POSEN
WEST BANK
SWENODA
CASHEL
DUBLIN
PILLSBURY
KRAGERO
BIG BEND
MANDT
GRACE
LOURISTON
WOODS
TUNSBURG
ROSEWOOD
HAVELOCK
LONE TREE
SPARTA
LEENTHROP
STONEHAM
GRANITE FALLS
MONTEVIDEO
WATSON
MILAN
MURDOCK
DE GRAFF
KERKHOVEN
SWIFT FALLS
MYERS
MINNESOTA FALLS
EAST GRANITE FALLS
MINNESOTA FALLS DEPOT
MINNESOTA RIVER
Lac Qui Parle
Shakopee L.
Black Oak L.
Willow L.
Lone Tree Lake
L. Hassel
Camp L.
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
SWIFT AND CHIPPEWA COUNTIES
BY WARREN UPHAM
Explanation
Recent — Alluvium
Glacial — Modified Drift.
Till, undulating or rolling.
Till, more prominently rolling, morainic.
Archæan — Gneiss, Schists, Granite and Syenite
Contour Lines are shown approximately for each 50 feet above the sea
PIONEER PRESS CO. LITH. ST PAUL

CHAPTER VIII.

THE GEOLOGY OF SWIFT AND CHIPPEWA COUNTIES.

BY WARREN UPHAM.

Situation and area. Swift and Chippewa counties (plate 39) lie in the west part of Minnesota. They are wholly within the basin of the Minnesota river, and this stream forms their southwestern boundary. Montevideo, the county seat of Chippewa county, is 125 miles west from Saint Paul and Minneapolis, 100 miles north from the Iowa line, and 36 miles east from Dakota. Benson, the county-seat of Swift county, is 25 miles north from Montevideo. The other towns and villages are Kerkhoven, Murdock, De Graff and Clontarf in Swift county, on the Breckenridge line of the Saint Paul, Minneapolis & Manitoba railway, and East Granite Falls, Watson, Milan and Appleton in Chippewa county, on the Hastings & Dakota division of the Chicago, Milwaukee & Saint Paul railway.

Swift county has the form of a long rectangle. It contains twenty-one townships, having seven from east to west and three from north to south, each six miles square, excepting Appleton, which lacks about two sections cut off from its southwest corner by the Minnesota river. The area of Swift county is 757.73 square miles, or 484,945.44 acres, of which 9,392.08 acres are covered by water.

Chippewa county has an approximately triangular outline. Its length on its north boundary, where it adjoins Swift county, is about 39 miles, and its greatest extent from north to south is 27½ miles. The area of Chippewa county is 594.21 square miles, or 380,297.10 acres, of which 10,027.23 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Pomme de Terre and Chippewa rivers, which here unite with the Minnesota, the former flowing through western Swift county, by Appleton, and the latter through the centre of Swift county, by Benson, and the west part of Chippewa county, to Montevideo, are the largest affluents received by the Minnesota river from its north side along its entire course. Only two small streams join the Pomme de Terre river in Swift county, the larger of these being the outlet of lake Griffin in the northwest corner of the county. The East branch of the Chippewa river, which drains the northeast part of Swift county, Shakopee creek, which drains its southeast part, and Dry Weather creek, which enters the Chippewa river in the north part of Tunsburg, are its most important tributaries in these counties, all from its east side. The southeast part of Chippewa county belongs to the basin of Hawk creek, which reaches the Minnesota river in the west edge of Renville county.

Lac qui Parle, an expansion of the Minnesota river, about ten miles long and from a quarter of a mile to one mile wide, lies on the southwest side of Kragero, the most western township of Chippewa county. This county has frequent sloughs which are covered by water in spring, but it posseses only few permanent lakes. The most noteworthy are Black Oak lake, one and a half miles long from east to west, five miles east of Montevideo; Shakopee lake, two miles long from north to south, in the northwest corner of Louriston; Willow lake, also about two miles long from north to south, crossed by the north line of Stoneham; and Lone Tree lake, two miles long from east to west, through which Hawk creek flows in the east part of Lone Tree township.

Several lakes of considerable size, varying from one to four miles in length, and trending from north to south or southeast, lie in northwestern Swift county, west of the Pomme de Terre river. The largest of these are lake Griffin, lake Henry, lake Oliver (or Long lake), and Shible lake. In the northeast part of this county, Benton township contains lake Hassel, of irregular form with an area of about one square mile, besides three others near this of less extent; and Camp Lake township takes its name from a lake about one mile long in its northeast corner.

Topography. Nearly all of Chippewa county, if we except valleys worn by streams, and the greater part of Swift county, are moderately undulating, the elevations and depressions, which differ only 10 to 20 or 30 feet in hight, being made by long smooth slopes. These undulations are too small to be observed in an extensive view, so that the traveler across the prairie sees it stretch away on all sides in an approximately flat plain. The highland of Langhei in Pope county, about a dozen miles north from Benson and 350 feet higher, affords a very fine prospect of this expanse, extending south and southwest to the horizon, which it meets in a line almost as level as the sea.

In the northeast part of Swift county, Kerkhoven and most of Camp Lake township consist of irregular massive hills of till, 75 to 125 feet above the valleys and lakes, being part of a belt of morainic drift which extends from northwest to southeast. Again, in the northwest corner of this county, Hegbert township has a somewhat rolling contour, its highest swells and short ridges being 30 to 40 or 50 feet above the numerous lakes. Here and in most portions of both these counties, the trend of the elevations and of the intervening sloughs is prevailing from northwest to southeast; but the undulations vary much in both width and hight or depth, and are seldom distinctly continuous more than one or two miles.

The only considerable flat area observed is a tract of modified drift which extends several miles about Benson and borders the Chippewa river in Clontarf, Six Mile Grove and Swenoda, reaching one to two miles or more away from the river, above which its hight is only 10 to 20 feet. From the southwest part of Swenoda to its mouth the Chippewa river flows in a valley that increases in depth from 50 to 100 feet and in width from a sixth to a third of a mile in West Bank and Big Bend, but is a half mile to one mile wide from the centre of Tunsburg to Montevideo, eroded in the glacial drift or till, which forms the bluffs on each side.

The similar valley of the Pomme de Terre river in Fairfield is 75 feet deep and about a mile wide. Toward its mouth this valley expands to an area of lowland several miles wide, 50 feet below the general surface of the drift-sheet and only 25 to 40 feet above the river. This tract occupies the southeast half of Shible and nearly all of Appleton township. It consists partly of modified drift, nearly level, and partly of till, often very stony, with a smoothly undulating surface or occasionally in numerous little knolls and short ridges.

On the southwest boundary of these counties the Minnesota valley is from one to two miles wide, and from the mouth of the Pomme de Terre river to Lac qui Parle and Montevideo is about 100 feet deep, having here a less depth than in any other part of its extent from Big Stone lake to its mouth. Below Montevideo its depth increases to about 150 feet at Granite Falls and 185 feet below Minnesota Falls, where it is crossed by the line between Chippewa and Renville counties. The erosion of this valley was effected by the river Warren (vol. I, page 622), the outlet of the glacial lake Agassiz.

The valleys of the Pomme de Terre and Chippewa rivers, 75 to 100 feet deep along most of their course, and one-fourth mile to one mile in width, were probably also avenues of drainage from the melting ice-fields in their northward retreat. Between these rivers, in the twenty-three miles from Appleton to Montevideo, the glacial floods at first flowed in several channels, which are excavated 40 to 80 feet below the general level of the drift-sheet, and vary from an eighth to a half of a mile or more in width. One of these, starting from the bend of the Pomme de Terre river one and a half miles east of Appleton, extends fifteen miles southeast by Milan to the Chippewa river near the centre of Tunsburg. This old channel is joined at Milan station by another, which branches off from the Minnesota valley, running four miles east-southeast; it is also joined at the northwest corner of Tunsburg by a very notable channel which extends eastward from the middle of Lac qui Parle. The latter channel, and its continuation in the old Pomme de Terre valley to the Chippewa river, are excavated nearly as deep as the channel occupied by the Minnesota river. Its west portion holds a marsh generally known as the "Big slough." Lac qui Parle would have to be raised only a few feet to turn it through this deserted valley.

Elevations, Breckenridge line, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Shakopee creek, water, 1084; grade,	116.49	1090
Kerkhoven,	117.77	1108
De Graff,	126.75	1061
Summit, cutting 15 feet; grade,	131.96	1066
Benson,	134.07	1047
Chippewa river, water, 1020; grade,	134.92	1035
Clontarf,	140.00	1044

Elevations, Hastings & Dakota division, Chicago, Milwaukee & Saint Paul railway.

From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from Hastings.	Feet above the sea.
Line between Renville and Chippewa counties, grade,	140.7	1047
Minnesota Falls,	141.2	1041
Granite Falls,	143.3	941
Palmer's creek, grade,	145.7	921
Brofee's creek, grade,	151.3	932
Cut 10 feet in rock, grade,	154.7	948
Montevideo,	156.6	927
Chippewa river, water, 913; grade,	156.8	930
Top of bluff, grade,	159.4	1009
Watson,	162.9	1029
Beginning of descent, grade,	164.1	1028
Depression, grade,	167.0	937

	Miles from Hastings.	Feet above the sea.
End of ascent, grade,	169.0	993
Milan,	171.7	995
Two miles farther northwest, grade,	173.7	1019
Summit, grade,	177.1	1035
Appleton,	179.8	1007
Pomme de Terre river, water, 978; grade,	180.1	1007
Line between Swift and Big Stone counties, grade,	184.1	987

The hight of the Minnesota river at ordinary low water, on the boundary of these counties, is approximately as follows:

Minnesota river.

	Feet above the sea.
At the mouth of Pomme de Terre river,	934
Lac qui Parle,	926
At the mouth of Chippewa river,	913
Above Granite Falls,	908
Below Granite Falls,	870
Below Minnesota Falls,	856
At the line between Chippewa and Renville counties,	852

The highest land of Swift county is about 1,150 feet above the sea, which elevation is reached by the hills in the northeast part of Hayes, and in Kerkhoven and Camp Lake, the most northeastern townships of the county; and again in its northwest part this hight is attained in Tara, Fairfield and Hegbert. Its lowest land is the shore of the Minnesota river, which at the mouth of the Pomme de Terre is 934 feet above the sea, being only about two hundred feet lower than the highest portions of this county. The estimated average hights of the several townships are as follows: Kerkhoven, 1,125 feet above the sea; Hayes, 1,110; Pillsbury, 1,105; Camp Lake, 1,100; Kildare, 1,070; Dublin, 1,070; Benson, 1,075; Torning, 1,050; Cashel, 1,050; Clontarf, 1,050; Six Mile Grove, 1,040; Swenoda, 1,045; Tara, 1,110; Marysland, 1,080; West Bank, 1,060; Fairfield, 1,100; Moyer, 1,070; New Posen, 1,060; Hegbert, 1,120; Shible, 1,075; and Appleton, 1,000. The mean elevation of Swift county, derived from these figures, is approximately 1,075 feet above the sea.

The highest land of Chippewa county, about 1,100 feet above the sea, is in Woods and the north part of Lone Tree, its most northeastern townships; and the lowest is along the Minnesota river, 930 to 852 feet above the sea. Estimates of the mean hights of the townships are as follows: Woods, 1,100 feet above the sea; Lone Tree, 1,080; T. 117, R. 37, 1,075; Louriston, 1,075; T. 118, R. 38, 1,070; Stoneham, 1,060; Grace, Havelock and Leenthrop, each 1,060; Granite Falls, 1,025; Mandt, 1,060; Rosewood, 1,055; Sparta, 1,000;

Big Bend, 1,050; Tunsburg, 1,015; and Kragero, 1,010. The mean elevation of Chippewa county is approximately 1,050 feet above the sea.

Soil and timber. The entire area of Swift and Chippewa counties has a very productive soil, consisting of clay with which some sand and gravel are intermixed. It is the unmodified glacial drift or till. Decaying vegetation year by year during centuries has blackened and enriched the upper one or two feet of this deposit, called the soil. This gradually changes within the next foot to the subsoil of yellowish till, weathered to this color through a depth of ten or twenty feet or rarely more, below which it is dark blue, as found in deep wells. Limestone in boulders and pebbles and in a finely pulverized condition is present as a considerable ingredient of the drift, and contributes much to its fertility. Wheat, oats, corn, sorghum, flax, potatoes and other garden vegetables and fruits, stock-raising and dairy products are the varied resources of agriculture in this part of the state.

Timber is found in these counties only in narrow belts along streams and in small groves on the borders of lakes, all besides being natural prairie or grassland, ready for pasturage, mowing or plowing, with no tree nor shrub on tracts often several miles in extent. Among the species of trees are basswood, white or soft maple, box-elder, wild plum, green ash, white elm, red or slippery elm, hackberry, bur oak, ironwood, and cottonwood. The shrubs include prickly ash, smooth sumach, frost grape, Virginian creeper, climbing bitter-sweet, choke-cherry, red and black raspberries, the wild rose, prickly and smooth goosberries, black currant, red-osier dogwood, wolfberry, elder, sweet viburnum or sheep-berry, and willows.

GEOLOGICAL STRUCTURE.

Archæan rocks. The only outcrops of rocks underlying the glacial drift are in the Minnesota valley or in deeply eroded tributary valleys. The rocks thus exposed are gneiss of Archæan age, allied with the syenite, granite and gneiss of Saint Cloud and the adjoining region and of a large area farther north, reaching from the lake of the Woods nearly to lake Superior. Thick drift deposits cover the greater part of the country occupied by these rocks in Minnesota, but they are doubtless continuous and constitute the floor on which the drift lies, excepting that probably thin patches of Cretaceous beds intervene in many places, from the international boundary south to the Minnesota valley.

In Appleton, the only township of Swift county that lies on the Minnesota river, and thence southeast to the middle of Lac qui Parle, no rock-outcrops were noticed. West from the bay on the east side of Lac qui Parle in section 33, Kragero, this lake contains an island of rock, and two ledges were seen on its southwest shore. About two miles farther southeast, or one and a half miles above the foot of the lake, are several small and low exposures of rock, occurring at each side and also as islands. On the northeast side this is gneiss, mostly with N. E. to S. W. strike. Its dip was clearly shown at only one place, being there 75° S. E.

In the deserted channel between Lac qui Parle and the Chippewa river, rock is exposed near the southeast corner of section 6, Tunsburg. It also is seen at the southeast corner of this township, in the bottomland on the east side of the Chippewa river, three miles above its mouth. Another low exposure is one mile west of Montevideo, half-way between the river and the bluff. Close south of Montevideo, a knob of gray gneiss, nearly vertical in lamination, with W. S. W. strike, rises 30 feet above the bottomland. One to two miles southeast from Montevideo are extensive outcrops of gneiss, rising 40 to 60 feet and extending one and a half miles from the river to the bluff at its northeast side. At a little lake near the river its dip is 45° S. 10°–20° E. Adjoining this, the gneiss incloses a mass of hornblende schist, twenty rods long from northwest to southeast and from twenty feet to six rods wide. Its dip is 33° S. E. by S. At the railroad-cut two miles southeast from Montevido the rock is reddish gray gneiss, dipping 45° to 60° S. E. In the line of strike of these ledges, another exposure of this rock is found farther northeast, in a ravine in the north part of section 21, Sparta, about half a mile from its junction with the Minnesota valley. Two and a half miles southeast from the railroad-cut, a small outcrop of the same rock was seen in the bottomland in section 34, Sparta, close southeast of a little creek and southwest of the railroad, rising some 40 feet above the river.

At Granite Falls and Minnesota Falls ledges of gneiss occur 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, their outcrops along this distance being mostly on the southwest side of the river. The prevailing strike is nearly from northeast to southwest, and the dip is commonly from 25° to 40° towards the S. E. The strata are reddish or gray gneiss, which is frequently so disintegrated by the weather that its outcrops have become turfed, varying occasionally to more enduring gray and red granites. These rocks also sometimes contain 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. The gneiss, also seen here in contact with this bed, dips 60° S. E. At the northeast end of the Minnesota Falls bridge and dam the rock is flesh-colored gneiss, much contorted and obscure in dip, which in one place was seen to be 30° S. E. It is intersected by many joints. Gray syenite, probably valuable for building and ornamental purposes, has been slightly quarried on the left side of the river, in Chippewa county, about a half mile south from 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 mainly are 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, to the vicinity of the county line.

Remarkably water-worn surfaces were noted on the southeast slopes of the ridge of rock cut by the railroad two miles southeast of Montevideo, and of another a few rods distant toward the west. In the top of the southwest side of the railroad-cut, 45 feet above the river, is a pot-hole eight feet deep, three or four feet in diameter in its upper part and one and a half feet near its bottom. Fifteen feet west from this is another pot-hole, ten inches in diameter. On the northeast side of the cut, thirty feet east from the one first mentioned, a third is seen, fully eight feet deep and one and a half to two feet in diameter, inclined 70° S. E., conforming nearly with the dip of the rock. Three others, each extending about five feet below the surface of the rock, are also seen on the northeast side of the cut, within twenty feet southeast from the last. All of these, excepting the second, have been half cut away in the excavation for the railroad. At Granite Falls the outcrops of rock are water-worn in many places 20 to 30 feet above the river.

The most northwestern localities where decomposed and partially kaolinized gneiss was observed, are in a ravine north of the river opposite Minnesota Falls, and at a depth of five feet beneath the surface in the N. E. ¼ of section 26, Tunsburg, near the deposit of travertine that has been burned for lime.

Remnants of Cretaceous beds, spared by glacial erosion, probably lie between the Archæan rocks and the drift in some places in these counties, but no observations of them were obtained in the examination of the Minnesota valley, nor by the wells recorded in the following pages.

Glacial and modified drift.

Glacial striæ, seen at several places on the outcrops of gneiss in East Granite Falls, bear S. 45° to 50° E., referred to the true meridian. The drift in these counties presents nearly the same features that have been described for it in the three preceding chapters. It consists mainly of till, averaging probably a hundred and fifty feet in depth, and is spread with a nearly uniform, moderately undulating contour, having a much more even surface than the underlying rocks where they are exposed to view in the Minnesota valley.

Terminal moraines. The northeast corner of Swift county includes the edge of a belt of morainic hills accumulated on the northeast side of a lobe of the ice-sheet in the last glacial epoch, and belonging to the time of formation of its Waconia and Dovre moraines. This ice-lobe covered the basins of the Red and Minnesota rivers, and continued south in Iowa to Des Moines. Successive moraines were formed at its farthest limit and its lines of halt or temporary re-advance during its final recession. The southwest boundary of this ice-lobe probably crossed Chippewa and Swift counties when the fifth, sixth, and seventh, or Elysian, Waconia and Dovre moraines were being formed. A specially rolling belt close west of Granite Falls, extending from southeast to northwest, and an unusually rolling and knolly surface in Kragero, the southwest part of New Posen, and the southeast of Appleton, lying southwest of the deserted channel that reaches from the Pomme de Terre river by Milan to the Chippewa river, appear to represent the Elysian and Waconia moraines. The Dovre moraine is probably traceable through Swift county in a west-northwest course, indicated by more irregular contour and more plentiful boulders than ordinary, but it does not here form a distinct and conspicuous belt. It may include a narrow ridge, 25 to 40 feet high, partly composed of till and partly of stratified sand and gravel, which is cut by the railroad two miles east of Benson and extends a half mile north and a mile or more south of the railroad, blending with scattered hillocks on the south; another ridge, similarly 25 to 40 feet high, sprinkled with many boulders, extending from southeast to northwest, near the middle of the west line of Six Mile Grove, with a swell

10 feet above the general level, bearing abundant boulders, in section 30, and a depression containing many boulders, in section 31 of this township; and, especially, the ridges and swells or knolls, often strown with a multitude of boulders, which occupy the most of Hegbert township and the north part of Shible, trending mostly from northwest to southeast and rising 25 to 40 feet above the adjoining lakes.

A buried moraine. A stratum distinguished by its remarkable abundance of boulders, supposed to be the buried moraine of some earlier glacial epoch, is contained in the till, at a depth of 40 to 50 feet below the general surface, along this part of the Minnesota valley, in which it usually produces a narrow shelf or terrace upon the bluffs. From Appleton west to Correll in Big Stone county, this rocky layer in the drift-sheet has caused an extensive plain to be left in the process of erosion, 50 feet below the top of the bluffs and from 75 to 50 feet above the river. It is plentifully strown with boulders, and in some portions these occur in heaps and patches covering half the ground. Southward from the Pomme de Terre river and Appleton, this stony tract, bearing many boulders of all sizes up to ten feet in diameter, continues nearly to the head of Lac qui Parle, diminishing in width from four to two miles and elevated 25 to 50 feet above the river. On its higher eastern portion, near the line between Swift and Chippewa counties, four nearly flat-topped boulders, each marked with striæ bearing southeast, were observed within a distance of forty rods along the road, probably indicating a plane in the drift where it was subjected to glacial erosion.

The old water-courses southeast of Appleton frequently have their bed upon this stony stratum. In sections 8, 19 and 20, Kragero, the bottoms of these channels, from an eighth to a quarter of a mile wide, are almost paved with boulders of all sizes up to ten feet. For two miles east-southeast from the southeast corner of section 29, Kragero, a bluff 40 to 50 feet above Lac qui Parle is continuously strown on its verge and front with very abundant small and large boulders. They are also seen in great abundance on the bluffs of the channel that extends east from Lac qui Parle and contains the "Big slough," especially in section 6, Tunsburg, where a very rocky narrow terrace is formed on each bluff 40 or 50 feet above the railroad and slough. A well 70 feet deep in the southwest quarter of this section, at the house of Nils Nelson, formerly Wren post-office, situated on the general level of the surrounding country, about 90 feet above the Big slough, encountered this stony layer 35 to 40 feet below the surface. This well was soil, 2 feet; yellow till, 38 feet, the last five feet containing many boulders up to two feet in diameter; and yellow sand, 30 feet, to water. The well of the elevator at Watson station, situated four miles farther southeast and 110 feet above the Minnesota river, found this stratum 50 feet below the surface. Its unfinished section, noted when it had reached the depth of 55 feet, was soil, 2 feet; yellow clay, with no rock-fragments nor gravel, 18 feet; gravel, 1 foot, containing a little water; and blue till, 34 feet, and continuing deeper, in which a layer of boulders up to one foot in diameter was found at 50 feet.

The bluffs of the Minnesota valley on each side of Lac qui Parle, and southeastward to Montevideo and Granite Falls, usually show about 40 feet below their top a boulder-covered terrace or bench, one to three rods wide; and knolls and small ridges of boulders, doubtless fallen from this stratum in the erosion of the valley, are found at many places on the bottomland. Nearly all of the boulders mentioned in this and the foregoing paragraphs, as also in the drift generally throughout these counties, are granite, syenite and gneiss. The explanation of these observations which seems most probable, is that a terminal moraine, accumulated here in an early part of the ice age and consisting originally of mounds and hills of coarsely rocky drift, has become spread in a nearly level stratum and deeply buried in the drift-sheet under the eroding and leveling action and additional deposition of drift by the more extended ice-sheet of a later epoch.

Red till. Besides the section figured and described on page 628 of volume I, showing red till in an excavation at the base of the bluff east of the Chippewa river in Montevideo, a further note is found, stating that the same red till was observed also in the bluff east of the Kitchel Brothers' mill in Montevideo, being seen to have a thickness of about fifteen feet, without showing either its upper or lower limits. Its probable origin has been discussed in volume I and in the preceding chapter, which mentions another observation of it in Renville county.

Modified drift. The low plain of modified drift, consisting of stratified clay and sand, which borders the Chippewa river in Swift county, and the tract, partially composed of gravel and sand belonging to this formation, adjoining the Pomme de Terre river in Shible and Appleton, have been already described in treating of topography. The ridge cut by the railroad two miles east of Benson is in part kame-like gravel and sand; and knolls or short ridges, 10 to 30 feet high, of such irregularly interbedded gravel and sand are found infrequently on the surface of the smooth, nearly level sheet of till in nearly all portions of these counties. In the vicinity of De Graff their prevailing trend was observed to be from north to south or southeast.

A terrace of modified drift, consisting of sand horizontally stratified but with its layers often obliquely bedded, elevated 25 to 40 feet above the Minnesota river, extends with varying width along a distance of about four miles from Brofee's creek in section 35, Sparta, northwest to the outcrops of rock at the north side of section 29, two miles southeast from Montevideo. It is mostly narrow and inconspicuous, but reaches its greatest hight, in its southeast portion; its greatest width is about half a mile, in section 29, Sparta. Between this terrace and the river is the alluvial bottomland of recent formation, only about ten feet above the river and annually overflowed by it.

Wells in Swift county.

Pillsbury. The section of a boring made for a railroad well at Kerkhoven station under the superintendence of Mr. T. S. Nickerson, is reported by him as follows: till, yellowish near the surface and dark bluish below, reached to the depth of 140 feet; next was fine quicksand, 45 feet, so loose that it often rose, filling fifteen or twenty feet of the pipe; then blue clay mixed with fine white sand, 15 feet, to a total depth of 200 feet, where the boring could not be carried farther and was abandoned.

Kildare. Wells at De Graff station find excellent water 15 to 25 feet below the surface. The section is soil, 2 feet; yellow till, about 20 feet; then usually a thin bed of sand; underlain in the deepest wells by blue till, which is quite hard, requiring to be picked. Small fragments of lignite are occasionally found in the till throughout this region.

P. Moran; sec. 32: well, 25 feet; soil, 2; all below is yellow till, spaded, becoming harder in its lower part; water seeps, affording only a scanty supply.

Dublin. John Madden; sec. 5: well, 20 feet; soil, 2; yellow till, spaded, 11; sand, 1 foot, with some water; then harder blue till, 6 feet, yielding no additional supply of water.

Benson. E. A. Smith; sec. 6: well, 22 feet; soil, 2; yellow till, 10; harder blue till, 10; water rose from the bottom ten feet.

In Benson village the well at the public school, 30 feet deep, is soil, 2 feet, below which it is all yellowish stratified clay, with no gravel nor sand; two or three feet of water. A Thornton's well in this village, also thirty feet deep, is yellow clay, 18 feet, and sand and fine gravel, 12 feet, with water good in both quantity and quality.

Clontarf. At the railroad station the wells are mostly only 10 to 15 feet deep, with plenty of good water. The section is soil, 2 or 3 feet; yellow clay, 1 foot; with yellowish clayey sand below.

Six Mile Grove. Mitchell McDaniel; sec. 32: well, 34 feet; soil, 2; yellow till, spaded, 15; sand, 1 foot, with only a little water; and harder blue till, picked, 16 feet; water, springing up in this blue till, probably from a vein of sand or gravel close below, rose ten feet in one hour. This well has contained a depth of ten to fifteen feet of water five years; yet its sides, unprotected by wall or curbing, show no caving in.

Swenoda. John D. Lyons; sec. 6: well, 36 feet; yellow till, 30 feet, some portions of it including whitish streaks of calcareous matter; and harder blue till, 6 feet, at which depth a spring of water was found, rising fifteen feet in a few hours.

William McCabe; sec. 8: well, 37 feet; soil, 2; yellowish till, containing portions unusually reddened by iron (limonite), 8 feet; blue till, 27 feet; water, 18 feet deep, seeping from sandy streaks, mostly near the bottom.

Maryland. Frank Kaufman; sec. 32: well, 25 feet deep, all in yellow till; the deepest well in this vicinity.

West Bank. Moses Shellenbarger; S. E. ¼ of sec. 5, near Cottonwood creek: well, 11 feet; sand, 8; quicksand, 3, yielding a large supply of water.

A. Shellenbarger; S. W. ¼ of this section, a half mile west from the foregoing, and on land ten feet higher: well, 9 feet, all in yellow till, spaded; plenty of water.

Fairfield. Thomas Coleman; N. W. ¼ of sec. 17: well, 29 feet; soil, 2; yellow till, spaded, 25; much harder blue till, 2; water came in slowly at the junction of the yellow and blue tills, rising fourteen feet.

Hegbert. John Ormond, in the S. W. ¼ of sec. 1, dug 70 feet in till, finding no water; but within a distance of six rods, on land of nearly the same hight, a good supply of water was obtained at 30 feet.

Francis Nugent; S. W. ¼ of sec. 10: a well dug 40 feet deep without water is only four rods from another, 26 feet deep, in which water rose from its bottom fourteen feet.

Shible. W. H. Squire; S. E. ¼ of sec. 14: well, 32 feet; soil, 2; yellow till, mostly picked, 30; water comes from a gravelly streak, three inches thick, level all around the well, 22 feet below the surface.

Appleton. The well at the elevator of E. R. Hoyt & Son, 40 feet deep, found gravel and sand, 25 feet; and hard, blue clay, 15 feet; underlain by gravel and sand, which yields a scanty supply of water. At Norrish, Baker & Countryman's elevator, about twenty rods farther east, the same section was found, but a much larger supply of water, which rose twenty feet in one hour from the gravel and sand at the bottom.

A. W. Lathrop's well, 45 feet deep, a half mile southwest from the village, was soil, 2 feet; sand, 6; gravel, 20; a layer of very coarse gravel, containing rounded stones from six inches to two feet in diameter, underlain by a layer of white sand, a few inches thick, the two together being about 2 feet; then coarse gray sand, 10; and fine gray sand, 5 feet, with water.

Wells in Chippewa county.

Louriston. F. A. Barrager; sec. 6: well, 26 feet; soil, 2; yellow till, picked, 8; blue till, spaded, 15; sand, 1 foot, from which water rose twelve feet in a week.

Grace. P. Martin; sec. 28: well, 42 feet; soil, 2; yellow till, spaded, 22; much harder blue till, 15; sand, 3 feet, with small supply of water.

Havelock. T. L. Cosino; sec 12: well, 30 feet; soil, 2; upper till, spaded for the first eight feet, but picked below, 24 feet; softer blue till, 4 feet; water rose quickly twenty-four feet from gravel at the bottom, rising the first twelve feet in two minutes. Pieces of lignite up to eight inches in diameter were found in this well.

Rosewood. Henry R. Mettling; sec. 22: well, 25 feet; soil, 2; yellow till, spaded, 23; water rose ten feet in one day from sand at the bottom. John Mettling's well, in the same section, 44 feet deep, was soil, 2; yellow till, 18; harder blue till, 15; and yellowish gravel and sand, 9; water of excellent quality is found in the lower part of this gravel.

L. L. Morton; sec. 28: well, 27 feet; soil, 2; yellow till, spaded, 8; harder gray till, 10; very hard blue till, 7 feet, picked two feet and bored below; after boring five feet, the auger fell about six inches, and water rose rapidly eleven feet. Another well in this section, 23 feet deep, on land of Mrs. L. S. Morton, was soil, 1½ feet; clayey gravel, 5½ feet; and fine gravel and sand, 16 feet, with water in its last five feet. This well, consisting of modified drift, is on a short kame-like ridge, trending from northwest to southeast, 15 feet above the general level.

E. S. Warner; sec. 34: well, 27 feet; soil, 2; yellow till, spaded, 6; harder blue till, 19 feet, picked, excepting its last five feet which were bored; the auger then fell about a foot, and water rose ten feet in a few hours.

Sparta. Henry Seman; sec. 4: well, 28 feet; soil, 2; yellow till, 11; gravel, 6 inches, yielding a good supply of water; below which this well was bored 14 feet in soft and sticky blue till, containing no veins of water nor stratified layers. Andrew Brainerd's well. 40 feet deep, in the same section, is all sand and fine gravel, with plenty of water at the bottom. Both these wells are on swells 25 or 30 feet above the adjoining land, the former being glacial drift, and the latter kame-like deposit of modified drift.

Edward Thomas; sec. 8: well, 50 feet; all yellow and gray till, very hard and picked beyond the first five feet; water seeps, affording a scanty supply.

Jacob Jenson; sec. 2, in the southeast corner of this township: well, 25 feet; all yellow till, picked, excepting its upper ten feet; water rose from the bottom about four feet.

Montevideo. John B. Lawrence's well, on the general level of the surrounding country, 100 feet above the river, is 26 feet deep, being soil, 2; yellow till, 18; and blue till very much harder, 6; water ame up rapidly twelve feet from quicksand, rising the first six feet in as many minutes.

Tunsburg. Nils Nelson's well in section 6, and the well of the elevation at Watson, each containing a stratum of boulders, have been already described on a preceding page.

Tolef Jacobson; sec. 12: well, 53 feet; soil, 2; yellow till, spaded, 20; blue till, harder, 25; and gravel and sand, 6 feet, with water. E. O. Erickson's well, in the same section, a half mile farther south, is 30 feet deep, in yellow till, 25 feet, spaded for the first ten feet, but picked below; and much harder blue till, 5 feet; water, found in gravel at the bottom, rises four feet.

Kragero. The railroad well at Milan station, situated in the old Pomme de Terre valley, 50 feet below the average hight of the country on each side, is 165 feet deep and obtains a flow of water rising eight feet above the surface. The section is soil, 2 feet; sand, 10 feet; and till, 153 feet. The water comes from a white sand which was bored into only one or two feet. This is the only flowing well learned of in these counties.

Edward K Sylte; S. E. ¼ of sec. 22: well, 25 feet; soil, 2; sand, 3; hard yellow till, 10; and harder blue till, 10; water rose from the bottom eight feet.

MATERIAL RESOURCES.

The fertile soil of these counties, and their agricultural resources, have been already noticed.

Water-powers. The following utilized water-powers are all employed for flouring mills:

On the Pomme de Terre river the mill of Barton & Powell, one and a half miles above Appleton, has a head of eight and a half feet; and the Appleton mill, owned by Lathrop & Thompson, has a head of eleven feet. In its next two miles this river is said to fall twenty feet; and its whole descent, from Appleton to its mouth, a distance of about four miles, is forty-four feet.

On the East branch of the Chippewa river the mill at Swift Falls, in section 3, Camp Lake, had a head of eleven feet at the date of the examination of these counties, in 1879; but a change in location of the mill, to a point about a fifth of a mile farther down the stream, was being planned, by which its head, receiving the water by canal, would be increased to twenty-two feet.

On the Chippewa river are Graham & Gilbert's mill, in the southeast corner of section 34, West Bank, with a head of nine feet; and the Montevideo mill, owned by the Kitchel Brothers, having a head of seven feet.

Four powers are used on the Minnesota river in its course on the boundary of Granite Falls township, but the mills are all on the southwest side of the river, in Yellow Medicine county. They are 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. This river at Granite Falls and Minnesota Falls averages about 150 feet wide. It usually has sufficient water for running the mills during the driest part of the year.

Building stone. The outcrops of rock in the Minnesota valley have been very slightly quarried at a few points, the most promising of which is half a mile south of Minnesota Falls. Most of these outcrops have too contorted and irregular bedding, and too variable texture for this use. Boulders, found scantily on the greater part of these counties, but very abundant in some localities, have furnished much of the masonry for foundations and cellar walls, the curbing of wells, and culverts of roads.

Lime has been burned from magnesian limestone boulders by Amundson Brothers, Aaron Clark, James Irwin, and E. R. Harkness, all in Tunsburg. The aggregate yearly product is only a few hundred barrels, sold at $1.50 per barrel. It is white lime of excellent quality. Hardly one in a hundred of the very abundant boulders referred to the buried moraine is limestone.

A deposit of travertine, or "petrified moss," occurring in the N. E. ¼ of section 26 and the south part of section 23, Tunsburg, has also been considerably burned for lime by Mr. Harkness, who states that it yields a nearly pure, white lime, fully as strong as that of boulders. It here forms a nearly level layer two to three feet thick, extending fully a half mile as shown by frequent exposures upon the side of the bluff of till northeast of the Chippewa river. Only its southeast portion is adapted for lime-burning, the rest being gravelly. It appears to mark a line at which springs issued because of impervious beds above or below it. These springs are now partly intercepted by a tributary ravine thirty rods northeast, in which "petrified moss" is forming along a distance of about an eighth of a mile, at a hight of three to six feet above the rill.

Another deposit of similar travertine, not however of amount or quality to make it available for lime-burning, was seen in an excavation on the upper side of the road three-quarters of a mile southeast of Montevideo. It is close east of a short ravine, and was exposed along a distance of forty feet, with a thickness of one or two feet, being two to three feet above the roadway.

Bricks. At De Graff, a quarter of a mile west from the depot, 300,000 bricks were made in 1877. They were cream-colored and of good quality, selling at $10 per thousand. The soil was removed to the depth of six inches, and the next five feet were used, consisting of the lower part of the soil and yellow clay, which are free from gravel. A tract of several acres here seems to have a subsoil of this kind.

Red bricks have been made in Montevideo by Nils Swennungson, producing 60,000 yearly, selling at $6 to $10 per thousand. This clay is in the southeast part of the town, on the general level of the upland, 100 feet above the river. The section is soil, 1½ feet; yellow clay, used for brick-making, 3 feet; clayey sand, 6 inches; with clay containing limy concretions below.

At Watson station a similar deposit of yellow clay, free from gravel and probably suitable for brick-making, reaches to a depth of about twenty feet,

CHAPTER IX.

THE GEOLOGY OF KANDIYOHI AND MEEKER COUNTIES.

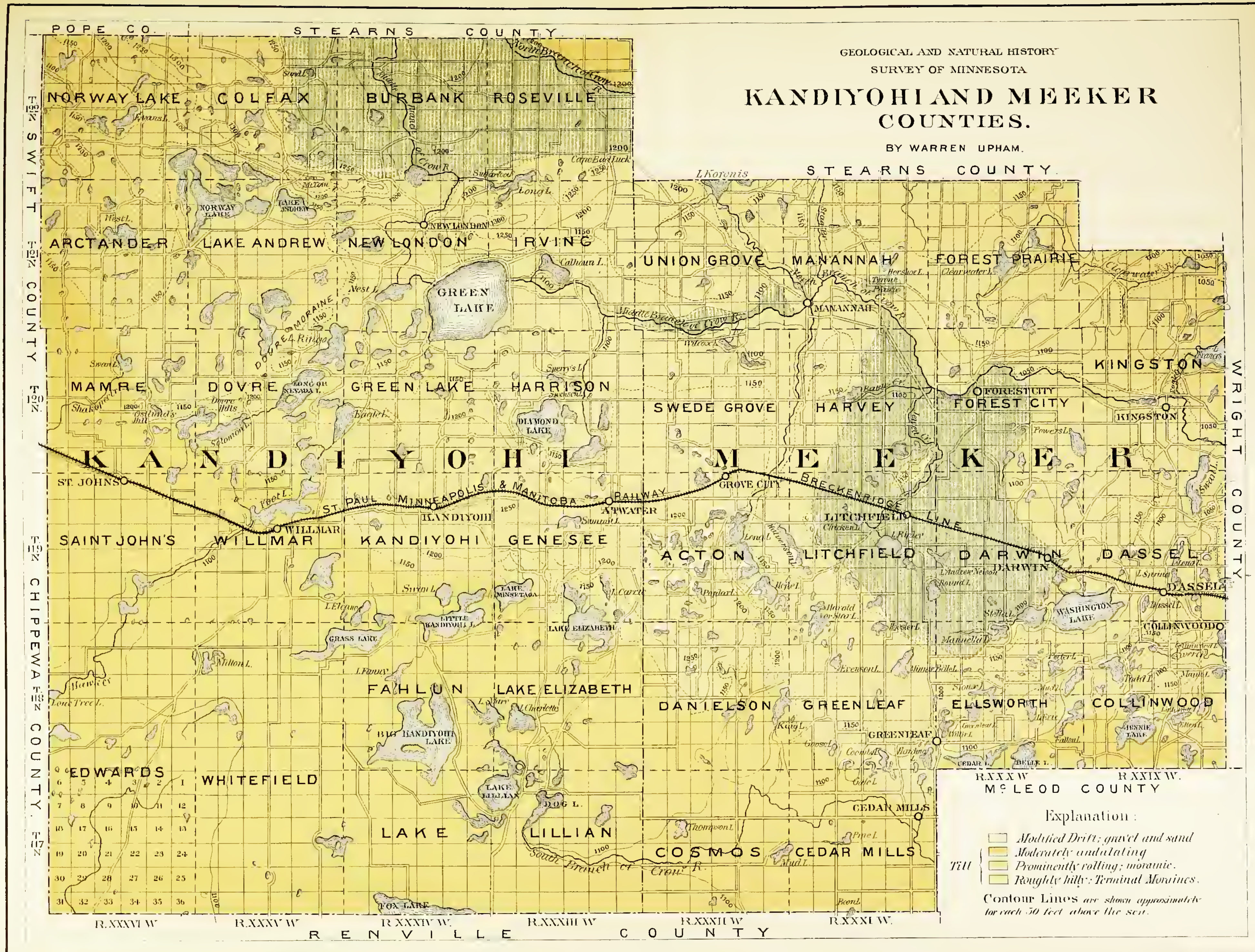
By WARREN UPHAM.

Situation and area. Kandiyohi and Meeker counties (plate 40) are situated adjoining each other, the former west of the latter, in the central part of the state, about midway between the Minnesota and Mississippi rivers. The geographical centre of Minnesota is some sixty miles north of their north line. From the east side of Meeker county to the boundary between Minnesota and Wisconsin at Stillwater is 70 miles; from the south line of these counties to the boundary of Iowa is 96 miles; and from the west side of Kandiyohi county to the Dakota boundary is 60 miles.

Litchfield, situated near the centre of Meeker county, of which it is the largest town and county-seat, is distant about 60 and 70 miles, respectively, in a straight line drawn a little to the west of north, from Minneapolis and Saint Paul. Willmar, similarly the largest town and county-seat of Kandiyohi county, and near its centre, is 25 miles due west from Litchfield, being thus about 85 and 95 miles west from Minneapolis and Saint Paul.

Other important towns and villages in Kandiyohi county are Atwater, Kandiyohi and Saint John's on the Breckenridge line of the Saint Paul, Minneapolis & Manitoba railway, which crosses the central part of the counties from east to west; and New London, on the south fork of the north branch of Crow river, 14 miles north-northeast from Willmar. The towns and villages of Meeker county, besides Litchfield, are Dassel, Darwin and Swede Grove, on this railway; Kingston, Forest City and Manannah, in the northern part of the county, on the north branch of the Crow river; and Collinwood, Greenleaf and Cedar Mills, in its southern part.

Kandiyohi county has a length from north to south of six townships,


GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
KANDIYOHI AND MEEKER COUNTIES.
BY WARREN UPHAM.
Explanation:
Modified Drift; gravel and sand
Till { Moderately undulating; Prominently rolling; morainic; Roughly hilly; Terminal Moraines.
Contour Lines are shown approximately for each 50 feet above the sea.
POPE CO.
STEARNS COUNTY
WRIGHT COUNTY
SWIFT COUNTY
CHIPPEWA COUNTY
RENVILLE COUNTY
McLEOD COUNTY
KANDIYOHI
MEEKER
ST. PAUL MINNEAPOLIS & MANITOBA RAILWAY
BRECKENRIDGE LINE
NORWAY LAKE
COLFAX
BURBANK
ROSEVILLE
ARCTANDER
LAKE ANDREW
NEW LONDON
IRVING
UNION GROVE
MANANNAH
FOREST PRAIRIE
MAMRE
DOVRE
GREEN LAKE
HARRISON
SWEDE GROVE
HARVEY
FOREST CITY
KINGSTON
SAINT JOHN'S
WILLMAR
KANDIYOHI
GENESEE
ACTON
LITCHFIELD
DARWIN
DASSEL
FAHLUN
LAKE ELIZABETH
DANIELSON
GREENLEAF
ELLSWORTH
COLLINWOOD
EDWARDS
WHITEFIELD
LAKE LILLIAN
LILLIAN
COSMOS
CEDAR MILLS
GREEN LAKE
DIAMOND LAKE
BIG KANDIYOHI LAKE
WASHINGTON LAKE
T. 117 N.
T. 118 N.
T. 119 N.
T. 120 N.
T. 121 N.
T. 122 N.
R. XXXVI W.
R. XXXV W.
R. XXXIV W.
R. XXXIII W.
R. XXXII W.
R. XXXI W.
R. XXX W.
R. XXIX W.

each six miles square, and a width of four townships, thus including twenty-four townships of the governmental surveys. It is organized in twenty-one civil townships, the three most southern, namely, Lake Lillian, Whitefield and Edwards, being each twelve miles long and six miles wide. The area of Kandiyohi county is 867.14 square miles, or 554,969.04 acres, of which 57,867.69 acres are covered by water.

The maximum extent of Meeker county from north to south is five townships, or thirty miles, but in its eastern part this length is reduced to only three and a half townships; its greatest width from east to west is four townships, twenty-four miles. This county includes seventeen and a half townships of the governmental surveys. It is organized in seventeen civil townships, each being six miles square, excepting Kingston, which is nine miles long and six wide. The area of Meeker county is 633.62 square miles, or 405,518.58 acres, of which 24,075.56 acres are coverd by water.

SURFACE FEATURES.

Natural drainage. Nearly half of Kandiyohi county, upon its west side, is drained to the Minnesota river, by Chippewa river and Hawk creek. This portion has numerous lakes of considerable size, but its water-courses are small and are mostly dry during a part of the year. The remainder of this county is tributary to the Crow river. In its southeast part, lake Elizabeth, the Kandiyohi lakes, and lake Lillian, are the extreme sources of the south branch of this river. Toward the northeast, Green lake lies in the course of the south fork of the north branch of Crow river, and many smaller lakes discharge their surplus waters into that stream. Still farther northeastward the longer north fork of this north branch flows through Roseville, the most southeastern township of this county.

Green lake, nearly round and about three miles in diameter, is the largest in Kandiyohi county. Other lakes worthy of note in its vicinity and tributary to the same stream are Nest lake in New London, Calhoun lake in Irving, each nearly two miles long, and Diamond lake, of somewhat larger size, in Harrison. Lake Lillian and lake Elizabeth, whose names are also borne by the townships in which they principally lie, are each about three miles loug, with quite irregular outlines. A little farther west, and apparently tributary with the preceding to the south branch of the Crow river, are Little Kandiyohi and Big Kandiyohi lakes, and Waganga or Grass lake, each about four miles long. A group of lakes north of Willmar, at the head of Hawk creek, includes Foot lake, Eagle, and Long or Nevada lake, which are from two to four miles long, and others of smaller size. Farther northwestward, Norway lake, about four miles long and of very irregular form, and lake Andrew, about two miles loug, with several other lakes as large as the latter, and many from a quarter of a mile to one mile in length or diameter, lie in Dovre, Mamre, Lake Andrew, Arctander, and Norway Lake townships, upon the eastern margin of the basin of the Chippewa river.

Meeker county is drained by the north and south branches of the Crow river, excepting an area of about fifty square miles in its northeast corner, in which are the sources of the Clearwater river. The north branch of the Crow river flows in a winding course through the north part of this county, its general direction being toward the east-southeast. A mile east of Manannah, this is joined by the centre branch of the Crow river (which is a south fork of the north branch), coming from Green lake in Kandiyohi county; and at nearly the same place it receives a more southern affluent, from Long and Hope lakes in Acton. The other principal tributaries to the north branch of the Crow river in this county are the creek that is the outlet of lake Ripley in Litchfield, having its junction two and a half miles west of Forest City; Eagle creek, the outlet of Hutchin or Francis lake, coming in from the north a mile east of Kingston; the outlet of Washington and Stella lakes, situated at the southeast corner of Darwin, which has its junction one and a half miles south of the last; and the outlet of Swan, Collinwood, and numerous other lakes, received about a mile farther east.

North of this basin, the north part of Kingston and most of Forest Prairie are drained by the upper part of Clearwater river, the principal head of which is Clearwater lake at the centre of Forest Prairie township.

Through Cosmos and Cedar Mills, in the southwest part of Meeker county, flows the south branch of Crow river, which has its source a few miles farther west in the large lakes of southern Kandiyohi county. The largest tributary of this stream in Meeker county is that on which the village of Cedar Mills is located, this being the outlet of Cedar, Willie and Harding lakes. The area belonging to the basin of the south branch in this county is about a hundred and fifty square miles.

Meeker county has many lakes, the largest of which is Washington lake, lying at the south side of the railroad between Dassel and Darwin; its length, from east to west, is three miles, and its greatest width a little over one and a half miles. Other lakes of considerable size are Jennie and Todd lakes in Collinwood, and Collinwood lake, crossed by the east line of this township; Stella lake, crossed by the north line of Ellsworth, and Belle and Cedar lakes upon its south line; Manuella, Mud, Fallon, Sioux, Greenleaf and Willie lakes, within this township; Minnie Belle and Evenson lakes in Greenleaf, Harold lake crossed by its north line, and Harding and Coombs lakes by its south line; Pipe lake, in Cedar Mills township, so named because of its outline; Thompson lake in Cosmos; King's lake, at the east side of Danielson; Long and Hope lakes in Acton, and Halverson lake on its east line; lake Ripley in Litchfield, and lake Andrew Nelson and Round lake on its east line; Dassel, Long, and Swan lakes, in Dassel; Hutchin lake on the east line of Kingston; Clearwater lake in Forest Prairie; Wilcox lake in Swede Grove; and lake Koronis or Cedar lake, crossed by the north line of Union Grove. More than a hundred lakes are shown on the map of this county, having a length of a half mile or more; besides many others of smaller area, though a large proportion of the small lakes are not delineated.

Ice-formed ridges. Low ridges of gravel, sand, and boulders, a few feet high and three to six rods wide, occur along the edge of many of the lakes of these counties. They have been formed, and are still in the process of formation, being added to or changed in outline, by the ice of ordinary winters. A good example is afforded at the south side of the shallow lake in section 17, Litchfield. This ridge is composed of gravel and sand, with few if any boulders; it is five to eight feet high, two or three rods wide, and about thirty rods long. The road runs upon it, between the reed-filled lake on the north and a marsh on the south at the same level with the lake. Another ridge, similar to this, borders the northwest side of Round lake in Litchfield for a third of a mile.

In Kandiyohi county, a notable ice-formed ridge of this kind, composed of gravel and sand, occurs at the east side of Green lake, extending about a half mile south from its outlet. This ridge is covered by trees, and the highway runs along it, while on its east side is a treeless marsh scarcely higher than the lake. Another very fine ridge occurs on the northwest side of Diamond lake, close west of J. H. Gates' house. It is four to six feet high and two to three rods wide. It is very steep, being nearly vertical on the side away from the lake. This extends fifteen or twenty rods. It is composed of coarse boulder-drift. An ordinary ridge is also seen thence for most of the way through one and a half miles along the west side of Diamond lake. About the north end of Nevada or Long lake, ridges recently formed by ice are finely exhibited, being two to eight feet above Nevada lake; sometimes three to four rods broad and mainly sand; in other portions narrow and containing boulders up to three or four feet in diameter. Marshes, often of several acres, and ponds up to a third of an acre in extent, are thus separated from the main lake, as is done by beach-ridges of the ocean. Big Kandiyohi lake has an ice-ridge of sand and gravel, with few or no boulders, along its east side, five to seven feet high, and three to six rods wide, dividing the lake from a marsh. Lake Lillian is bordered on its south side for a half mile or more by a very interesting ice-ridge, five to seven feet high, narrow and of variable hight, often interrupted, bearing frequent boulders up to six feet in diameter. This ridge is the more striking because all this region is very level, its highest portions seldom reaching more than ten feet above the lakes, while it probably averages not more than five or six feet above them. The lakes have very slightly descending shores, so that they are mostly bordered and filled at their edges with tall marsh grasses, sedges, and rushes.

Topography.

Kandiyohi county. Very irregular morainic hills, composed principally of till or the unmodified glacial drift, form a well-marked series in the north part of Kandiyohi county, being the eastern half of a remarkable line of these hills which reaches east-southeast more than forty miles from near the east end of lake Emily in Pope county to Koronis or Cedar lake, at the northwest corner of Meeker county. It is part of the great moraine formed by a lobe of the ice-sheet whose central current pushed from the vicinity of lake Winnipeg and the Red river valley toward the south and southeast. This belt of hills enters Kandiyohi county at its northwest corner, and through the north part of Norway lake and the southwest part of Colfax, it averages three miles in width. These hills are 50 to 150 feet high, their highest elevations being a half mile north of the north end of Norway lake.

The description of the view to be seen from a hill about 100 feet above this lake, and situated a little more than a mile north of it, in section 13, Norway Lake, gives a fair idea of the contour which marks this morainic series. My notes, written on the top of this hill, state that east and northeast for a mile all is low, with countless low knolls and short ridges of different trends, with two or three ponds. On the northeast and north, at a distance of two or three miles, the land rises in irregular broken hills to nearly the same hight with this in section 13. All these are unwooded. Toward the north-northwest and northwest are very irregular wooded hills, two or three miles distant, 100 to 150 feet high. These are the wooded area of the south part of Lake Johanna township, in Pope county, extending into the north edge of Norway Lake. At the west-northwest, in section 10, and thence northwestward, are very irregular hills, 75 to 100 feet high, destitute of woods. The contour between these areas and section 13 consists of very numerous low knolls and ridges, five to fifteen feet high, interspersed with occasional lakelets. The view to the west-southwest is only moderatety undulating, in swells 10 to 50 feet high. A little east of south are the high hills already spoken of north of Norway lake. The most distant point seen in this view are the Dovre hills, Mount Tom, and (a little north of the range of the last) the wooded hills north of Green lake. No prevailing trend is apparent in the ridges and hills of this region, it being sometimes from east to west, or nearly so, and elsewhere from north to south.

In a line a little south of east from the north end of Norway lake, is a series of three other lakes, the last being lake Andrew, extending about six miles. A very fine exhibition of the ridges and hills constituting a typical moraine is seen for nearly two miles along the north side of the first of these lakes. These hills terminate on the south in a nearly continuous east and west ridge, 50 to 75 feet high, very steep toward the south. At the north side of lake Andrew the highest hills are nearly upon the north line of the township of this uame, one mile from the lake. The highest point, called Mount Tom, is in the southeast corner of section 35, Colfax. This hill is 90 feet above the road at its north side, and about 100 feet above the general level of the country northward; it is 125, or perhaps 140 feet, above lake Andrew. It is a very steep, nearly conical mound, composed of till, with many angular boulders, mixed with a large proportion of water-worn gravel, as shown by a small excavation at the highest point. The largest blocks seen on this knob are four feet in diameter; these are not more numerous than generally in the till of Wright, Meeker and Kandiyohi counties; but the ground is uncommonly filled with very many small fragments up to one and a half feet in diameter. At one point, forty rods north-northeast, boulders up to six feet in diameter are very abundant, as many as thirty or forty occurring on a space one hundred feet square; mainly, however, large blocks are not specially abundant among these hills. In the view from Mount Tom, the contour for one mile east and for the same distance to the west-northwest, and for a quarter of a mile north to the road, is very irregular, in short east-to-west ridges, very steep and most so on their south side, with correspondingly irregular hollows. Low knolly land extends all the way south to lake Andrew.

The continuation of this terminal moraine seems to be eastward in low hills reaching along the north edge of New London. East of the central branch of Crow river, which flows through New London, this moraine rises into great prominence and covers an area fully three miles square, lying on the north side of Green lake, above which its hills are elevated 150 to 200 feet. These hills are all covered by woods. An outlying peak of smaller hight, in the southwest corner of Roseville, north of the west end of Long lake, is called Sugarloaf.

Six miles northeast from Green lake these hills cease to be wooded. Here, at the northeast corner of Irving and in section 36, Roseville, they are crossed by a road from south to north, this locality being commonly known as Cape Bad Luck. The belt of morainic hills at this point is about 1½ miles wide. It consists of very irregular elevations of every form, with no well-marked trends, rising 100 feet above the general level of the land south, and probably 150 feet above lake Koronis, which lies two miles farther east. The separate knolls and hillocks are from 25 to 50 feet high, with many enclosed hollows, which often contain little marshes or ponds.

The material of this whole range is till, with no considerable portions composed wholly of modified drift. It does not appear that this continuous range, traceable for a distance of forty miles in Pope and Kandiyohi counties, has any well established name; though, in the vicinity of Mount Tom, it is often called the "Blue hills." Their origin and accumulation were due to the movements of the ice of the last glacial epoch. At the time of their formation a vast lobe of the ice-sheet lay on their south and southwest side, and pushed out these drift materials at its border. Norway lake and others extending to lake Andrew, and Green lake, mark areas that were covered by the ice-margin while the terminal moraine at their north side was being accumulated. The plowing and excavating action of the ice may have been greater close to its margin than generally within the ice-covered area, thus causing the hollows that are filled by these lakes.

South-southeast from Mount Tom, this terminal moraine sends off a branch of very roughly irregular low hills, similar to itself in contour and probably marking the line where the southeast extremity of this ice-lobe was held nearly stationary during a considerable pause in its final recession. From a point a mile west of Nest lake, in the southwest part of New London, this recessional morainic belt extends southwest, occupying a width of fully a mile between lake Ringo and Nevada or long lake, on the southeast, and two unnamed lakes on the northwest, this course is continued to the Dovre hills, at the southwest corner of section 16, Dovre. These hills, a quarter of a mile apart, one being nearly due east from the other, are about 125 feet above the lake near at the south. The road passes between them, occupying a hollow perhaps 50 feet below their tops. Though so insignificant, these are the most prominent hills of this region, and, because of the lack of anything to compare them with, present a somewhat majestic appearance. They are composed of till, containing numerous boulders of sizes up to three or five feet in diameter, perhaps three times as many as the till averages to contain generally. They are also nearly paved with many small, chiefly angular fragments up to six inches in diameter, nearly all being granites and crystalline schists, perhaps one in twenty being limestone. The view to the northeast, extending some three or four miles, is very full of knolls, often quite rocky, 10 to 40 feet high, of characteristic morainic contour. The trend of these ridges and hillocks in the view eastward is mainly from north to south, or approximately so, while at the north side of the Dovre hills it is nearly from east to west. About five miles west from the Dovre hills is Ostlund's hill in section 22, Mamre, about 100 feet above the general level. This, and another of nearly equal hight a third of a mile southwest from it, terminate this well-marked range of drift-hills; beyond which westward the continuation of this seventh or Dovre moraine is inconspicuous and has not been traced.

A broad continuous depression, at the southeast side of this range, is occupied by a series of lakes from section 26, Mamre, to Nest lake in New London; and it is continued still farther east in Green and Calhoun lakes at the south side of the main series of these morainic hills. It is noteworthy that the large hollow occupied by Green lake lies directly south of the most prominent group of hills in the terminal moraine in Kandiyohi county; that is, it lies where the ice was exerting its eroding power while these hills were being heaped at its margin, the date of their accumulation being before the recession of the ice to the Dovre moraine.

In Roseville the terminal moraine is bordered at its north side for four miles by a flat of gravel and sand, extending from two to three miles in width to the North branch of the Crow river, in which distance it descends about 40 feet. This deposit was probably formed by floods, which were poured down from the ice-sheet at the same time that its adjacent terminal moraine was being accumulated. At lower stages of these waters, as in winter, channels were cut in this plain; one of these, containing a narrow lakelet, occurs close east of the school-house at the south side of section 22. Similar, but more extensive plains of modified drift are marked features in the topography of Long Island, Martha's Vineyard, Nantucket and Cape Cod, where they lie in front (which is there south) of terminal moraines, sloping away from them and crossed by old water-courses. Westward the contour gradually becomes more undulating in the west half of Roseville, and lies in swells 20 to 50 or 60 feet high in Burbank and northeastern Colfax. The material of these swells appears to be modified drift; its deposition was therefore by glacial floods. A rolling high prairie of till occupies the northeast corner of Roseville, and extends northward in Stearns county, having an elevation 75 to 100 feet above this branch of the Crow river, by which its southward continuation across Roseville was eroded during the departure of the ice-sheet.

Excepting this tract in Roseville, Burbank and Colfax, north of the terminal moraine, the surface of Kandiyohi county is till, with a prominently rolling contour for a distance of eight to fifteen miles south of the terminal moraine proper, these hilly tracts being a part of the morainic belt; while south of a line drawn approximately from the northwest corner of Mamre to the middle of the east side of Lake Elizabeth township, the contour is only gently undulating, its greatest hights being from 10 to 30 feet above the lowest depressions. An extensive tract of fertile prairie in Lake Lillian township is almost perfectly level, and only five to fifteen feet above the adjoining lakes. One of the highest portions of the hilly area associated with the moraine is found in the southwest corner of Norway Lake township. This area has its hills only 50 feet approximately below those of the moraine proper, five miles northeast. Its lakes are 30 to 40 feet lower. Another elevated area, of larger extent than the foregoing, is in the northeast part of Kandiyohi township and the north part of Genesee, where the summit grade of the railroad is 1,269 feet above the sea. The highest hills found in the course of the terminal moraine in Kandiyohi county are probably less than a hundred feet higher.

Meeker county. The central part of this county is occupied by a level plain of stratified gravel and sand, sometimes with beds of clay, extending ten to thirteen miles from north to south, and seven or eight miles wide. It includes the east half of Harvey, the northeast two-thirds of Litchfield, extends into the edge of Greenleaf and Ellsworth, and reaches east to Darwin station and north to Forest City. The level character of this deposit is shown by the exactly determined hights of the railroad, which has its two stations of Darwin and Litchfield, seven miles apart, only two and a half feet different in hight, while its line between these places is nearly straight and almost an unbroken level. The only island of till that rises above this plain of modified drift is the tract crossed by the road one mile north of Litchfield. This hill of till reaches one and a half miles to the northeast, rising some 40 or 50 feet above the surrounding modified drift. To the northwest from this area, the west part of Harvey and Swede Grove are only moderately undulating or nearly level, though composed of till, which both on the north and south is prevailingly hilly. The only other portion of this county which is nearly level is at the southwest, where Cedar Mills township, excepting its northeast part, Cosmos, and the south half of Danielson, are quite flat upon large tracts, and lack generally the undulating contour which usually marks the till. Wells and the sections made by streams, however, show that the material of this area is the same unmodified glacial drift or till, which elsewhere in this region is undulating, rolling, or hilly.

The greater part of Meeker county consists of this rolling or hilly till, being the eastern continuation of the great morainic belt which occupies (with more or less characteristic features) the north half of Kandiyohi county. The altitude of its swells and hills in Meeker county varies from 40 or 50 to 75 or 100 feet. These are most conspicuous about lake Koronis and eastward through the north part of the county. They are scarcely less in hight, and are equally irregular in form and grouping, and quite as rough and steep, in Dassel; while Greenleaf, the north part of Danielson, and Acton, have abundant massive swells and hills from 50 to 100 feet above the lakes which are contained in the hollows between them. Most of these elevations of till have their greatest length from north to south; but they have such unequal slopes, with buttresses, and hollows at their sides, and are generally so destitute of symmetry, that they seem to have no near relationship with the lenticular hills or drumlins of till found in New England. Though their trend is prevailingly from north to south or southeast, it is not very noticeable, and no true lenticular forms, like those that characterize the hills mentioned in New England, have been observed.

Only a small amount of erosion has been effected by the streams of Meeker county. The valley of the North branch of the Crow river averages about 40 or 50 feet below the general hight of the hilly land through which it flows. This seems to be mainly a natural depression, being nearly the same in contour as it was left at the retreat of the ice-sheet, and not due to excavation by this river. The valley of the Middle branch, in the south part of Union Grove, is occupied by a flat alluvial plain, varying from a quarter to half of a mile in width, and rising 10 to 30 feet above the stream. The North branch flows at the northern boundary of the Litchfield area of modified drift, The outlet of lake Ripley has cut a channel at Litchfield in this plain of modified drift to a depth of about 25 or 30 feet. Its lower portion in the township of Harvey lies through extensive marshes, which seem rather to be areas on which the deposition of sediment was deficient than to have been excavated by the stream. To such inequalities of deposition must be ascribed the existence of hollows occupied by lakes which occur frequently upon this plain. The channel which the South branch of the Crow river has excavated through the nearly level till of Cosmos and Cedar Mills is from 15 to 25 feet deep; it has no considerable areas of bottomland.

Elevations, Breckenridge line, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Collinwood creek, water, 1020; grade,	63.93	1027
Stream flowing north, water, 1027; grade,	64.97	1042
Dassel,	66.43	1089
Summit, grade,	67.55	1121
Washington creek, water, 1066; grade,	68.75	1089
Summit, grade,	69.55	1122
Darwin,	71.76	1132
Litchfield,	77.69	1129
Outlet of lake Ripley, water, 1106; grade,	78.24	1116
Outlet of Long lake, water, 1142; grade,	84.00	1154
Grove City,	85.44	1192
Anderson's hill, cutting 15 feet; grade,	88.74	1216
Atwater,	90.55	1211
At cut of 10½ feet, grade,	91.50	1242
Summit, cutting 3 feet, highest point on the Breckenridge line; grade,	95.42	1269
Kandiyohi,	98.00	1222
Willmar,	103.72	1129
Saint John's,	110.31	1121

In Kandiyohi county the highest hills of the terminal moraine in its course through the north part of Norway Lake township, southeastward to Mount Tom, and north of Green lake in New London and Irving, are 1,300 to 1,350 feet above the sea. Green lake, Foot lake, the Kandiyohi lakes, and lake Lillian, are estimated to be about 1,100 feet above the sea. The lowest points in this county, situated in its southern part, where Hawk and Chetomba creeks and the South branch of the Crow river flow across its boundary, are approximately 1,075 feet above sea-level. Estimates of the average hight of its townships are as follows: Roseville, 1,190 feet above the sea; Irving 1,180; Harrison, 1,150; Genesee, 1,220; Lake Elizabeth, 1,140; Lake Lillian, 1,110; Burbank, 1,200; New London, 1,175; Green Lake, 1,160; Kandiyohi, 1,180; Fahlun, 1,125; Colfax, 1,250; Lake Andrew, 1,160; Dovre, 1,160; Willmar, 1,125; Whitefield, 1,120; Norway Lake, 1,200; Arctander, 1,160; Mamre, 1,140; Saint John's, 1,120; and Edwards, 1,090. The mean elevation of Kandiyohi county, derived from these figures, is approximately 1,150 feet above the sea.

In the centre of Meeker county the plain on which Litchfield is situated has an average hight of about 1,125 feet. Its slope in the ten miles from the south part of Litchfield and Darwin northward to the North branch of the Crow river at Forest City, probably descends 25 feet or more. The morainic hills in the north and east parts of this county, and in Ellsworth, Greenleaf, Danielson and Acton, are mostly from 1,150 to 1,200 feet above the sea. Their greatest hight seems to be attained in Acton and the north part of Danielson, and in the northwest corner of the county, west of Koronis or Cedar lake, where they have an elevation of about 1,250 feet. The North branch of the Crow river enters the county, in lake Koronis, and in its south branch from Green lake, at a hight about 1,100 feet above the sea. It descends a hundred feet, approximately in this county, crossing its east line with a hight of about 1,000 feet, this being probably the lowest point in the county. Clearwater river, where it crosses the county line, has nearly the same hight, its source, Clearwater lake in Forest Prairie, being 1,075 or perhaps 1,100 feet above the sea. The South branch of Crow river in Cosmos and Cedar Mills, descends from 1,080 to 1,050 feet, approximately.

Estimates of the average hight of the townships of Meeker county are as follows: Kingston, 1,075; Dassel, 1,090; Collinwood, 1,100; Forest Prairie, 1,140; Forest city, 1,100; Darwin, 1,120; Ellsworth, 1,140; Manannah, 1,130; Harvey, 1,120; Litchfield, 1,140; Greenleaf, 1,160; Cedar Mills, 1,090; Union Grove, 1,150; Swede Grove, 1,150; Acton, 1,190; Danielson, 1,160; and Cosmos, 1,100. The mean elevation of this county, derived from the foregoing figures, is 1,125 feet above the sea.

Soil and timber. Both these counties have a very fertile soil and are unsurpassed in their agricultural capabilities. The surface of the till and modified drift is blackened by decaying vegetation to a depth that varies from one to three feet, being usually about two feet. Limestone as boulders or pebbles, and as a part of the fine sand and clay, is a principal ingredient of the drift, and is a valuable element of the soil to give it large and permanent productiveness. At the same time it causes the waters of wells and springs to be hard; and their mineral matter held in solution, mainly the carbonates of lime and magnesia, forms a scale on the inside of tea-kettles and the boilers of engines. The chief agricultural products of these counties, as generally throughout the state, are wheat, oats, corn, flax-seed, sorghum, potatoes, vegetables and the small fruits of the garden, hay, beef and pork, and milk, butter and cheese.

The principal areas in Kandiyohi county that are wholly or in large part covered by timber, are the southwest half of Burbank, the north edge of Lake Andrew township, New London, excepting its southwest portion, and the northwest half of Irving. The wooded tract north of lake Andrew and Nest and Green lakes, extends about fifteen miles from east to west. Farther south in this county nearly all its lakes are margined with timber, rarely in groves reaching a quarter or a half of a mile from the lake-shores; excepting southwestward, in Saint John's, Edwards and Whitefield, where the shallow lakelets often lack the accompaniment of trees.

Mr. Samuel H. Adams, of Green Lake post-office, in New London township, enumerates the following trees observed in that vicinity: bass, white or American elm, ironwood, and poplar, abundant; red, bur and black oaks, red or slippery elm, white ash, box-elder, and willows, common; wild plum, black cherry, and cottonwood, less frequent, the last, with red cedar, being found principally on lake-shores; butternut, black ash, large-toothed poplar, hackberry, and paper or canoe birch, rare; and of shrubs, climbing bitter-sweet, frost grape, hazel, smooth sumach, wild red cherry, wolfberry, rose, prickly ash, elder, and prickly wild gooseberry, common; high blackberry, choke cherry, thorn, high cranberry-bush, and smooth gooseberry, less frequent. The sugar maple, though not found about Green lake, occurs at Norway lake, ten miles to the west-northwest.

About half of Meeker county is wooded, or was originally covered with woods, including half of Union Grove township, nearly all of Manannah, all of Forest Prairie, Forest City and Kingston north of the North branch of Crow river, nearly all of Dassel, the east third of Darwin, all of Collinwood, and about four-fifths of Ellsworth. This area is a part of the Big Woods. In Harvey a belt of woodland two miles wide and five or six miles long extends southward from this forest. Acton, containing numerous lakes, also has extensive groves bordering them, occupying about a quarter part of the area of the township. The other townships in the southwest part of this county, including Swede Grove, Litchfield, Greenleaf, Danielson, Cedar Mills, and Cosmos, have only a very small proportion of woodland, chiefly limited to small groves beside lakes.

At a few places within the forest, areas of prairie are found. Such a tract, wholly destitute of timber or shrubby growth, is Tyrone prairie, in sections 26 and 27, Manannah; this is an area of level modified drift, spread by floods at the last withdrawal of the ice-sheet. Its extent is about one and a half miles from east to west, and two-thirds of a mile in width. In the southwest part of Forest Prairie, fires running in the woods have within the past twenty-five years killed the originally heavy growth of wood upon an area that extends three miles and is a mile or so in width, reaching southeastward nearly to Forest City. Over the whole tract are springing up the common poplar, the wild red cherry, and many shrubs, which, if not prevented by the recurrence of fires, would be succeeded at length by the ordinary forest of bass, elms, ash, oaks and maples. Repeated fires, however, keep these trees and shrubs mostly less than twenty feet high.

Nearly all of the wooded portions of this county are more or less hilly, being unmodified drift or till. The same material and contour also prevail upon certainly half of the prairie of the county, many parts of Greenleaf, Danielson and Acton being quite as boldly hilly as any portions of the forest, both being alike till. The large area of nearly level modified drift surrounding Litchfield has scarcely any considerable groves.

The following species of trees occur in Meeker county, the enumeration being in their estimated order of abundance: bass, white elm, black and bur oak, ironwood, common poplar, white and black ash, soft or red maple, wild plum, box-elder, large-toothed poplar, sugar maple, butternut, red elm, red oak, black cherry, cottonwood, and white birch; and of shrubs, arranged in a similar order, prickly ash, hazel, Virginian creeper, frost-grape, smooth sumach, wild red cherry, high blackberry, red raspberry, rose, black currant, prickly wild gooseberry, choke cherry, thorn, high cranberry-bush, and smooth wild gooseberry.

GEOLOGICAL STRUCTURE. THE DRIFT.

No exposure of rocks older than the drift is found in Kandiyohi and Meeker counties; nor has the drift been penetrated by wells in this district, though they occasionally exceed one hundred feet in depth. These counties are covered throughout by glacial and modified drift, the upper part of these deposits, and the contour of the surface, having been formed in the last glacial epoch, when the series of moraines that crosses Minnesota from Wisconsin to Iowa and Dakota was being accumulated. It seems quite certain that the two portions of the great northern ice-sheet, one of which moved southwestward from the region of lake Superior, and the other southward and southeastward from the region of lake Winnipeg, were confluent, during the greater part of that epoch, upon an area reaching from northern Dakota county northward by lake Minnetonka and Minneapolis, and thence northwestward one hundred and fifty miles to the Leaf hills, and even farther north to the lakes at the head of the Mississippi. An area or belt extending thus, with a width varying from forty to a hundred miles, has a junction and overlapping of the till brought from the northwest and northeast, and series of morainic hills, which appear to prove that this region was wholly covered by the ice of the last glacial epoch; that the line of confluence of its currents was shifted in the latter part of this epoch far to the east upon a large district southeast of Stearns county, bringing till from the west over that from the east; and that during the final melting and disappearance of the ice, probably at times when this was interrupted by its re-advance upon part of the ground from which it had retreated, true terminal moraines were formed upon the sides of this belt which had been wholly ice-covered through most of this epoch. The very distinct series of morainic hills extending from east to west and northwest through northern Kandiyohi county, described in respect to its surface features in the foregoing pages, is of this kind, being a terminal moraine amassed along the northeastern border of the ice-lobe which covered most of western Minnesota. The date of its formation was thus after considerable recession of the ice, so that it was not then nor ever afterward confluent with the portion of the ice-sheet which moved outward from lake Superior. An open land surface of modified drift, across which free drainage took place from this terminal moraine toward the north, is found in Roseville, as already described. In New London and eastward by Cape Bad Luck and the north side of lake Koronis, this moraine appears to have been accumulated while the southeast end of the western ice-lobe was at Waconia, being thus contemporaneous with the sixth or Waconia moraine of recession; and its portion farther west, in lake Andrew, Colfax and Norway Lake, belongs partly to the same date and partly to the time of the next pause in the glacial recession, when the seventh or Dovre moraine, extending from lake Andrew south and southwest to the Dovre hills, was being formed at the termination of this lobe, after its retreat from Waconia to Dovre, a distance of seventy miles.

The plain of modified drift surrounding Litchfield, about equal in extent to two townships, was spread by streams which descended upon this area from the melting ice-sheet. This gravel, sand and clay, whose beds make up this plain, had been contained in the ice, and were carried off and deposited here by the streams formed on the surface of the ice-fields. By such deposition unequal supplies of sediment were spread upon different portions of this area, so that depressions resulted in which we find lakelets like lake Ripley, lake Andrew Nelson, and Round lake, south of Litchfield. Or it is quite presumable that these hollows were produced by masses of the ice-sheet, still remaining where these lakes now are, during the period when the drift about them was deposited.

Kames. The only accumulation of drift resembling kames which was noted in Meeker county, is upon this area of modified drift, in section 23, Harvey. This is a nearly level-topped ridge, a small plateau with steep sides, extending about 1,000 feet from north to south, and 150 to 200 feet wide upon its top, which is about 35 feet above an extensive marsh by which it is nearly surrounded. This mass was probably deposited in its present form, instead of being an island left during a process of erosion. It is composed of gravel, little water-worn and very coarse, holding occasional boulders up to two feet in diameter. The upland adjoining this deposit on the northwest appears to be modified drift, being finer gravel and sand. This little plateau is regarded as a kame, owing its form to a glacial river that deposited it here upon an area from which the ice had melted, while adjoining parts of the ice yet remained as walls upon each side.

In Kandiyohi county kames of very coarse and rocky gravel and sand, stratified as shown by a cut for the highway, were observed in the northwest quarter of section 25, and the northeast quarter of section 26, Genesee, running nearly from east to west, and more or less noticeable along an extent of a half mile. The northernmost of the two ridges cut by the road is about a fifth of a mile long. and varies from 5 to 20 feet in hight. Within a hundred feet south of its west portion is another ridge of similar hight, which east of the road bends northward, so that a marsh covering about an acre is inclosed between the two. Westward and northward at the distance of a third of a mile, the land is some 30 feet higher than these kames, being swells of till about 75 feet above the neighboring lakes. A mile southwest from this locality, between lakes Carrie and Elizabeth, the contour is more hilly than is often seen in this region, being composed of morainic till in elevations 50 to 80 or perhaps 100 feet high.

Boulders. The only attempt at gathering boulders for walls, noticed in these counties, is in the northeast part of Danielson, where two or three short pieces of fence have a row of stones two feet high for their lower part. It may be added, also, that stone-walls constructed of boulders from the drift are equally rare in all parts of the state; indeed, the till in Minnesota generally, excepting in its morainic belts, has too few stones and boulders to make such fences, their supply being often less than would be desirable for building cellar-walls, wells, and the culverts of highways.

Limestone boulders and small fragments are numerous on Mount Tom; and they abound on the hill of section 13, Norway Lake, where they make up about a fourth part of all the smaller stones and gravel. Half of the pebbles in the gravel on the shore near the south extremity of Norway lake are limestone. Fragments of limestone are also abundant in the till of southeastern Kandiyohi county, forming sometimes a fifth part of all, the rest being granites and schists, which often are partially encrusted with carbonate of lime. Similar proportions of limestone are found in the till and the beach-gravel on lake-shores, and in the modified drift, throughout Meeker county, and generally through the west half of Minnesota. A small proportion of the larger boulders of the till, probably not more than one-twentieth upon an average, are limestone. The much greater part are chiefly granites, syenites, and crystalline schists, from the metamorphic Eozoic or Archæan rocks, by which the drift in these counties is probably underlain.

Wells in Kandiyohi county.

The following record of wells more fully illustrates the character of the drift deposits, which are the only geological formation to be seen in this district.

Roseville. P. Lagro; N. E. ¼, sec. 27: well, 12 feet deep; soil, 2 feet; yellow clay, 1 foot; gravel, containing pebbles up to six inches in diameter, 3 feet; and sand and gravel, 6 feet, to water.

Harrison. A. Heinz; S. W. ¼, sec. 13: well, 30 feet deep, all stratified gravel and sand.

William Reif; S. W. ¼, sec. 14: well, 55 feet; soil, 2; yellowish till, not very stony, 16 feet; harder bluish till, 27; softer material driven through, supposed to be sand or soft clay, 10 feet; from the bottom water rose in the pipe thirty-three feet in one hour, coming to a permanent level twenty-two feet below the surface.

C. Pagel; N. E. ¼, sec. 23: well, 60 feet, all till, yellowish above and dark bluish below.

P. A. Winnquist; N. W. ¼, sec. 24: well, 45 feet; yellowish till, about 10 feet; dark bluish till, about 25 feet; very coarse compact gravel, 5 feet; clay, 3 feet; and sand, with water, 2 feet.

Genesee. Wells at Atwater are reported by Mr. E. A. D. Salter to be yellowish till, 15 to 20 feet, containing but few pebbles, which are in large part limestone; succeeded by darker, blue till below, the bottom of which is not reached. Water comes from thin sandy or gravelly seams in the till, sometimes found only 15 to 20 feet below the surface, just beneath the upper yellow till, and elsewhere at a depth of 30 to 40 feet, in the lower till. The upper and lower portions of the till here differ but little in hardness. Small lumps of lignite are rarely found.

Mr. Marshall's well, about 1½ miles southwest from Atwater is till, 40 feet; dry sand, 10 feet, and sand saturated with water, 10 feet; having a total depth of 60 feet.

N. K. Brown, S. E. ¼, sec. 24: well, 25 feet; soil, 2; yellow till, 20; blue till, 3 feet.

Mr. Peterson's well, at the east side of sec. 32, is 12 feet deep, all in the yellowish upper till.

Lake Lillian. George W. Hart; sec. 12, near the southwest shore of lake Lillian: well, 40 feet; yellowish till, about 25 feet; blue till, about 15 feet; water comes from a vein of sand at the bottom.

O. C. Hart; post-office, sec. 7, at southeast side of lake Lillian: well, 36 feet; yellow till, 20 feet; blue till, 16 feet; water quickly rose twenty-five feet, from sand at the bottom. Several fragments of lignite were found in this well, 12 to 25 feet below the surface.

In Hans Hanson Sand's well, two miles east of the last, water found at a depth of about 35 feet in boring, was under sufficient pressure to suddenly lift up the auger.

New London. The well at the parsonage in New London village was 45 feet deep, all the way in stratified sand and gravel.

Louis Larson's well, also in the village, 30 feet deep, was gravel, 10 feet; clay, gray above and blue below, 20 feet; with gravel at the bottom from which water rose three feet.

Kandiyohi. John A. Berg; sec. 28: well, 54 feet; yellowish till, 20 feet; dark bluish till, twice as hard as the preceding, 34 feet, not dug through. The only water found seeps from the upper till. Several pieces of lignite, up to six inches in diameter, were found at about 40 feet. At his barn, some twenty rods farther west, on land of the same hight, another well, 62 feet deep, is yellowish till, 25 feet; sand, 2 feet; dark till, 5 feet; dark gravel and sand, containing water, 1 or 2 feet; and dark bluish till again below, 28 feet, and extending deeper.

Willmar. Wells in Willmar village are in till, and find water in their sandy veins at depths varying from 20 to 50 feet. Ole Johnson, who has dug many wells here, says that the upper, yellowish till is from 10 to 20 feet thick, underlain by a blue clay, less hard to dig, yet apparently a true till, with numerous rock-fragments.

M. Bertelson; north part of sec. 18: well, 14 feet; soil, 2 feet; yellowish till, 12 feet.

Lars Peterson; sec. 34: well, 45 feet; soil, 2; yellowish till, 15 feet; bluish till, 28 feet; to sand at the bottom, from which water rose thirty feet. The change in the color of the till was sudden, at a definite line; the yellow till was shoveled; the blue lower till is much harder and must be picked. Another well at Mr. Peterson's house, perhaps ten rods from the former and on ground four or five feet higher, was only 18 feet deep, finding water in a bed of sandy gravel next below the upper till. A piece of lignite, six inches in diameter, was found in the latter well.

Norway Lake. The well at Sunburgh post-office. in the N. W. ¼ of sec. 30, is 45 feet deep, all in till, yellow for about 15 feet, and blue below.

Mamre. Andrew Linberg, sec. 21: well, seen unfinished, at depth of 35 feet, had passed through 27 feet of yellow till and 8 feet of the blue till.

Lars Ostlund; N. W. ¼, sec. 22: well, 47 feet; soil, 2 feet; yellowish till thence nearly all the way down, 45 feet, much of it so hard that it must be excavated with a pick, containing rarely thin layers of sand, and near the bottom having two or three layers of dark bluish till, each about a foot thick; water seeps. About a dozen rods west from this, and on land some fifteen feet lower, the section of a well dug 60 feet deep in which no water was obtained, is as follows: soil, 2 feet; yellowish till, 15 feet; sand, 3 feet; dark bluish till, much harder than the upper till, 38 feet; and dry sand, 2 feet.

Wells in Meeker county.

Kingston. Adam Brower; S. W. ¼, sec. 16: well, 45 feet deep; soil, 2 feet; yellowish gray clay, free of pebbles, excepting limy concretions, 10 feet; blue clay, softer than the preceding, 7 feet; yellowish gray till, 23 feet, containing gravel and stones up to six or eight inches in diameter; water was then found, at 42 feet, in a layer of sand six inches thick; but as the water did not rise above its stratum of sand, the well was continued 3 feet lower, this being in a very hard gray till, thought to be at least twice as hard as that above, extending between 19 and 42 feet.

At Carville's mill, in sec. 14, a well situated below the dam, is 21 feet deep, all the way in till, the upper part yellowish, the lower part dark bluish and harder to dig.

About a third of a mile east of this mill, a well 36½ feet deep found the yellow upper till 14 feet thick; then 4 to 6 inches of sand, with some water; succeeded by 22 feet of dark bluish, very hard till.

Dassel. Several wells in the village of Dassel have found water at a depth of about 55 feet. The section is yellowish till, about 40 feet; succeeded below by much harder dark bluish till. Neither of these deposits has so frequent rock-fragments as to hinder boring wells.

Collinwood. Peter Melgaard; west part of sec. 2: well, 30 feet; soil, 2 feet; yellowish till, quite hard, 28 feet, containing water in sandy veins.

Briggs Smith; N. E. ¼ of sec. 10; well, 40 feet; soil, 2 feet; all below is yellowish till, mostly picked, 38 feet.

Forest Prairie. K. V. McKean; at west side of sec. 32: well, 65 feet; soil, 2 feet; yellowish till, 10 feet; much harder, dark bluish till, about 2 feet; then clean, white sand, dug 24 feet, and bored below to a total depth of 65 feet, through only sand and fine gravel, to a plentiful supply of water at the bottom.

James Lawton's well, also in the southwest part of Forest Prairie, 72 feet deep, is said to have passed through a stratum, 10 feet or more in thickness, of good mason's sand in its lower part.

Darwin. Wells at Darwin station, and for two miles to the west, reach water at depths varying from 20 to 30 feet, the section being through fine gravel and sand, all of it stratified.

Manannah. The well at J. A. Lee's hotel in Manannah village, 27 feet deep, was soil, 2 feet; and yellowish till, 25 feet, all picked below the first five or six feet from the surface; water came from quicksand at the bottom, rising ten feet. At Mr. Lee's farm, a mile to the southeast, the well, 21 feet deep, is in modified drift, being soil 2 feet, and only stratified gravel and sand below, finding water in a bed of coarse gravel.

John O'Keefe; S. W. ¼, sec. 34: well, 48 feet; soil, 3 feet; yellowish brick-clay, quite hard, 15 feet; yellowish till, dug with a spade, 5 feet; sandy yellowish clay, said to be free from gravel, 3 feet, yielding some water; yellowish till, dug with a spade, but very hard, 21 feet; at 47½ feet, from this very hard digging the spade went down suddenly a foot, and water came in fast, rising to be fifteen feet deep. A piece of blackened wood, one and a half feet long, was found in this well at 45 feet.

At Otho Campbell's store, in Manannah village, the well is 72 feet deep, as follows: soil, 2 feet; yellowish till, dug with a shovel for about ten feet, then gradually becoming harder, though not changing in color, so that it was picked for the next 20 feet; this till had occasional calcareous and sandy veins or seams from one-third to two-thirds of an inch thick. Next was encountered, at 32 feet, soft, wet and sticky blue clay, so soft as to be easily penetrated by a spade, to which it stuck; this was dug into about 18 feet, and was bored beyond to a total of 72 feet, without getting through it. Water seeps in from this soft blue clay, filling the well about half-way to the top. The two wells next following give further information of this deposit, and show that it reaches at least six or seven miles to the south.

Harvey. E. A. Price; sec. 18, four miles south of Manannah: well, 37 feet; soil, 2 feet; yellowish till, 20 feet, becoming harder, but not of different color, in its lower portion, as at Mr. Campbell's in Manannah; and similarly underlain by soft, sticky blue clay, free from gravel, but containing rare [floated?] boulders, sometimes as large as one foot in diameter, dug into about 15 feet, and extending lower. Some five feet below the top of this soft blue clay, it contained a layer of reddish sand six or eight inches thick, yielding water.

Three miles south of the last, in the southwest part of Harvey, a well is reported to have been bored 90 feet, finding the ordinary till about 30 feet deep, below which all the remainder was thought to be this soft blue clay.

Patrick Connole; west side of sec. 23: well, 72 feet; soil, 2 feet; yellow till, 20 feet; water-bearing sand, 1 foot; darker bluish till, 32 feet; soft, sticky bluish clay, nearly as in the preceding wells, 7 feet; and sand, growing coarser below, 10 feet, to water in coarse gravel at the bottom.

Litchfield. To Mr. J. W. Knight and Mr. E. M. Eastman of Litchfield, practical well-makers, I am much indebted for valuable information respecting the wells of this county, including several of the sections shown by wells here described. In Litchfield village, and upon an area reaching three or four miles east, as well as some distance from the village in other directions, the usual order of deposits found by wells, as reported by Mr. Knight is as follows: soil, 2 feet; hard and compact fine gravel, with some clay, about two feet; sand, with small amounts of fine gravel, about 16 feet; at this depth water is obtained by surface wells, in which it stands one to two or three feet deep; digging into the underlying strata causes the water to take a disagreeable taste; next below are 5 to 7 feet of "rotten clay," sometimes holding dark layers, perhaps affording vegetable remains in a decaying state, but never known to yield any lignite; then 6 to 10 feet of wet clayey quicksand; at 32 to 36 feet from the surface is usually a bed, 3 or 4 feet thick, of compact dark bluish clay, below which good water is found and rises to fill these deeper wells half-way to their top.

Andrew Smith; N. E. ¼ of sec. 2, on a ridge of glacial drift rising out of the plain of modified drift; well, 122 feet, the deepest in Meeker county; soil, 2 feet; yellowish till, 20 feet; dark bluish till, 90 feet, all the way nearly alike, about the same in hardness as the yellow till above; reddish quicksand, 5 feet; and gray gravel, 5 feet, with water, which rises eighty-one feet, standing permanently forty-one feet below the surface.

Greenleaf. On Ross & Becker's farm, in section 23, a well 48 feet deep was as follows: soil, 2 feet; gray and blue till of ordinary character, 43 feet; dark sand, disagreeable in smell, 6 inches, from which issued besides water a great amount of gas, probably chiefly carbonic acid, making a singing noise as it rose out of the sand; when this was first struck, a man was killed by breathing this gas; it continued to rise constantly and abundantly during six weeks, extinguishing fire in burning hay held over the mouth of the well; a depth of 2½ feet, bored below this gas-bearing sand, was hard till. This well was abandoned. Another well on this farm, 76 feet distant from the last, and 57 feet deep, was soil, 2 feet; till of the usual character, yellowish gray above, and below bluish, containing occasional stones up to six inches in diameter, 50 feet; "hardpan," apparently similar to the foregoing, but very hard, 6 inches; dark wet quicksand, with a smell like kerosene, but yielding little gas, 1½ feet; clay, 1 or 2 feet, and sand and fine gravel, 2 feet, yielding water which rises eight feet.

Patrick Manning; sec. 28: well, 85 feet; soil, dark, 4 feet; yellowish till, about 12 feet; darker, bluish till, very hard, about 35 feet; very dark "loam," appearing much like surface soil, so soft as to be very easily spaded, dug into 13 feet, then caving; but being bored a few feet lower, to a depth less than 70 feet in total, water came up plentifully and rose to be twenty feet deep; this was of very good quality, but in some seasons the supply failed, and the well was then bored or driven lower, to a total of 85 feet, the greater part of this last fifteen feet or more being in the soft "loam," beyond which it was very hard and the pipe driven was lost. No additional supply of water was obtained. In the thirteen feet dug into the "loam," many small pieces of lignite were found; a few fragments of it were also found in the till above. At the very bottom of the portion dug, 64 feet in depth, a piece of wood three inches long was found.

A second well at Mr. Manning's, about eight rods northwest from the last, and on land eight or ten feet lower, was soil, 4 feet; yellowish till, about 10 feet; dark bluish till, about 40 feet; "loam," similar to that of the preceding well, but with less lignite, 10 feet, to a total depth of 64 feet, where bluish sand was found, with water, which rose to be fifteen or twenty feet deep and is permanent.

William Emery; N. E. ¼ of sec. 35: soil, 1½ feet; yellowish till, 16 feet; bluish till, much harder, 2 feet, and extending lower; well seen unfinished.

Cedar Mills. L. J. Jones; S. E. ¼ of sec. 11: well, 29 feet; yellow till, 12 feet; blue till, 17 feet; water, found in a sandy vein at the bottom, rose about six feet.

Union Grove. Several interesting wells were found in section 33 of this township, all situated at the north edge of the plain of modified drift in the valley of the Middle branch of the Crow river, where that deposit is bordered by the higher rolling till, this line of boundary being about 30 feet above the stream. In their order from west to east these wells are as follows:

C. H. McCune: well, 26 feet; soil, 2; yellowish till, 18; bluish till, 6 feet, to water.

James Nicol, ¼ mile east from the last: well, 50 feet; soil 2; yellow till, about 10 feet; and blue till 38 feet; to gravel, with water, which rose thirty-five feet to a permanent level fifteen feet below the surface. Some water was found in this well at 12 feet, at the junction of the yellow and blue till.

A. G. Petrie, about a half mile northeast from the last: well, 92 feet; soil, 2; yellowish till, 12 feet; very much harder dark bluish till, probably 75 feet, but only a few feet at the top of this were dug, a pipe being driven the remaining depth, from which no material was brought up. At about 89 feet, the pipe encountered a very much harder layer than any of the rest of this very hard deposit. This being penetrated and found only about a foot thick, the pipe then went down suddenly about two feet, probably in quicksand; and water quickly rose to a level thirteen feet below the surface. This water has a mineral taste, and deposits an iron-rusty sediment in troughs and gutters.

Joseph Hubbard, a quarter of a mile east of the last: well, 45 feet, all the way in till, the last 30 feet being a driven pipe. Water in scanty supply was found at 15 feet, but rises plentifully from the bottom to 15 feet below the surface.

D. B. Hoar's well, in the west edge of sec. 34, a quarter of a mile southeast from the last, situated on the modified drift of the valley, finds an ample supply of water at the depth of 13½ feet, going through only stratified fine gravel and sand.

Swede Grove. Nels Hanson; S. E. ¼, sec. 16: well, 51 feet; soil, 2; yellowish till, with occasional thin seams of gravel and sand, 24; very hard, bluish till, 25 feet, to water, which came in from gravel. Another well, about four rods from the preceding, finds water at 15 feet, this depth being all stratified sand, which there takes the place of the upper part of the till.

Acton. The well at the elevator in Grove City, according to Mr. Wilcox, agent, is soil, 2 feet; yellowish till, about 18 feet; bluish till, 41 feet, containing a layer of sand six inches thick, thirty feet below the top of the well; water, struck at 61 feet, rose within one day to be about twenty-five feet deep. At C. E. Linberg's flour-mill, an eighth of a mile from the elevator and on the same level, the well goes through similar yellow and blue till, but to a less depth, finding at 32 feet a good supply of water which rises ten feet. At a blacksmith's shop here the well, 13 feet deep, went through 11 feet of the yellowish upper till, below which was a bed of caving sand, at least two feet thick and continuing lower. At Andrew Akerson's, in the northeast part of Grove City, a well dug 72 feet, without finding water, was as follows: soil, 2 feet; yellowish gray till, about 25 feet; and dark bluish till thence to the bottom and extending below. Mr. John S. Lyng, who has dug many wells in this vicinity, states that the yellow upper till varies from 15 to 25 feet in depth, there being a sudden change from this to the dark much harder lower till. Only thin seams of sand, from a few inches to a foot thick, or rarely thicker, occur in either of these deposits. The various depths at which water is found, in the same neighborhood, in sandy or gravelly veins in the lower till, seems to be due to the narrowness of such veins, so that different water-bearing layers are cut by these wells. The water's rising ten to twenty feet or more, shows that its veins have a considerable extent and varying hight.

Danielson. A well on Col. W. S. King's farm in sec. 25 is reported to be 111 feet deep, but the section was not learned.

Cosmos. James Twombly; sec. 22: well, 32 feet; yellow till, 12 feet; harder dark bluish till, 20 feet; water, found at the bottom in a vein of gravel, rose quickly about fifteen feet. This well caused some excitement, because many pieces of lignite, up to four inches in length, were found throughout the dark till and most plentifully near the bottom of the well. A piece of wood, not blackened, was also found here, twenty feet below the surface. Two other wells, less than a quarter of a mile distant toward the south, though dug in the same two kinds of till, found no lignite.

MATERIAL RESOURCES.

The fertile soil of these counties, which makes agriculture their chief industry, and their ample supply of timber, have been already noticed in the preceding pages.

Water-powers. Only two water-powers have been utilized in Kandiyohi county, both being on the Middle branch of the Crow river. These are at the

New London flouring-mill, owned by Adams, Larson & Sperry, which has twelve feet head; and the grist-mill about two miles to the south, at Green Lake post-office, owned by John & Samuel H. Adams, which has a head of eight feet.

In Meeker county the North branch of the Crow river has the following utilized powers: at Manannah, twelve feet head, reduced to eight feet at the lowest stage of water that can be used; at Forest City, eleven feet, obtained by flowing the river back four miles; and at Kingston, nine feet. Carville's mill on Eagle creek, one and a half miles northeast from Kingston, has twelve feet head. In the south part of the county, the mill at Collinwood has a head of eight and a half feet, but this is not permanent, and a steam-engine is used through part of the year; the mill at Greenleaf has ten feet head, and that of Cedar Mills about twelve feet, neither of these being reliable in a dry season. All these are flouring-mills.

Building stone. As the rocks underlying the drift have no exposures in these counties, their only supply of building stone from their own area consists of the boulders of the drift, which are much used for the foundations of buildings, for curbing wells, for culverts, and other rough masonry.

Lime. In Kandiyohi county lime is burned in small amount from boulders of magnesian limestone in the drift by John Torrisen in section 2, Norway Lake, producing about fifty barrels yearly, worth $1.50 per barrel; by Eric Dolberg and others, in the southeast part of Colfax; by G. S. Geer in section 27, Burbank; by William Reif, section 14, Harrison; and formerly in the south part of Roseville. Some of these boulders are white; others have a very light buff color. The latter are the more frequently fossiliferous; but the fossils are chiefly fragmentary, and determinable forms are seldom found.

The manufacture of lime from boulders has been done also in small amount at several places in Meeker county. The principal product is from Greenleaf, where Lewis Maher, one mile west of Greenleaf village, in the south part of section 26, has during the last ten years burned from 100 to 500 barrels yearly, selling at $1.50 per barrel. Andrew Evenson burns about 50 barrels yearly in the southeast part of section 7, Greenleaf. Others who burn lime in this township are Amund Peterson, in the west part of section 7, and John Olson on the east side of King's lake. John Henderson also burns lime in section 3, Danielson.

Bricks. The only brick-making in Kandiyohi county is that of Peter Larson, Jr., who has made bricks at the northwest side of Nest lake, in section 29, New London, since 1875. The bricks are cream-colored, with differences in tint according to the layers used and proportions of each. His yearly product is from 200,000 to 300,000, sold at $8 to $10 per thousand. On the average about one part of sand is used to mix with ten of clay. The opening for digging clay at the kiln is in the foot-slope of a swell that rises 30 feet or more above the lake. It has the same contour with ordinary swells of till; but excavation reveals the section illustrated in fig. 14. The base of the excavation is five feet above the lake. The upper stratum (*a*) is yellowish clay, finely laminated parallel with the surface, 4 to 5 feet in thickness; next below is sand (*b*), 1 to 2 feet; then clay (*c*), like the upper in color, but requiring more intermixture of sand for brick-making, 4 to 5 feet; and this is underlain, below the excavation, by a second bed of sand (*d*), of undetermined thickness, with water.

FIG. 14. SECTION AT NEST LAKE.

At a second pit, about twenty rods southeast from the last and similarly situated, being on the slope of the same swell, with the base of the excavation some five feet above the lake, there are 10 feet of yellowish clay, the upper portion most sandy, but having no layer that corresponds to the middle stratum of sand in the foregoing section. This clay as in that section is underlain by sand with water. The whole swell, comprising twenty acres, more or less, is formed of the same laminated clay, with no intermixed gravel. The laminæ conform with the outlines of the surface, being thus inclined at the ends of the sections in these clay-pits five degrees or more. The islands and other shores of Nest lake are till, of the same color with this brick-clay. The upper portion of this clay makes cream-colored bricks, while some layers in its lower part give reddish bricks.

The largest business of brick-making in Meeker county is that of Henry Ames, three miles northeast of Litchfield, on the way to Forest City. This business was begun in 1875. The yearly product is about 500,000, sold at $7 to $8 per thousand. One-fifth as much sand as clay is needed for tempering. The section here is soil, 2 feet; then gray clay, with irony stains, 8 to 10 feet; underlain by quicksand, yellowish gray, of undetermined depth, Through the summer an average of eight men and two mules are employed. This deposit of clay extends over an area of two hundred acres or more.

Another brick-yard, opened in 1879, is owned by Adam Brower, one mile west of Kingston, on the north side of the river. This clay is yellowish gray, appearing like that used by Mr. Ames. In both these clay-deposits, small flattened concretions of carbonate of lime occur in considerable numbers in certain horizontal layers three or four inches thick, while the rest of the clay contains scarcely any. The clay of Kingston needs one-eighth to one-fifth its own amount of sand. Mr. Brower's well, before described, is situated about four rods west from where the clay used for bricks is dug. This well and brick-yard are on a gentle swell, which was originally covered by white and bur oaks, elevated 20 or 25 feet above the adjoining land thirty rods south, which is the alluvial gravel and sand of the valley of the North branch of the Crow river. The deposition of this clay, as also of the clay worked for brick-making at Nest lake in Kandiyohi county, seems to have taken place in basins melted from the departing ice of the glacial period, the yet undissolved portions of the ice-sheet being walls on each side by which this sediment was kept from being spread over the adjoining lower land.

ABORIGINAL EARTHWORKS.

A very interesting group of artificial mounds was observed on the east side of Green lake in Irving, about a half mile south from its outlet. They are on a nearly level prairie, 20 to 25 feet above the lake, and the same hight above a marsh which lies north of these mounds and has a width of a half mile, being separated from the lake by an ice-formed ridge, on which are trees and a road. A map of this group of mounds, roughly sketched, is given in fig. 15. upon which are the outlines of its thirty-one circular mounds, six oblong mounds, and two embankments. The hight of these earthworks in feet is indicated by the annexed fignres. The embankment near the principal collection of the mounds is about two feet high and nine rods long, bearing S. 30° E.; and the eastern embankment, elevated only one foot and therefore scarcely noticeable when the grass is high, yet doubtless artificial, being straight for its whole length of twelve rods, bears S. 55° E., these directions being referred to the true meridian. This land is owned by Mr. William Taggart, who lives a third of a mile south from this locality. His sons have partially excavated the northernmost of the two mounds which are marked on the map as six feet in hight, and found within it a hollow chamber, dome-shaped, about three feet high, with a flat floor, which was on a level with the base of the mound. The

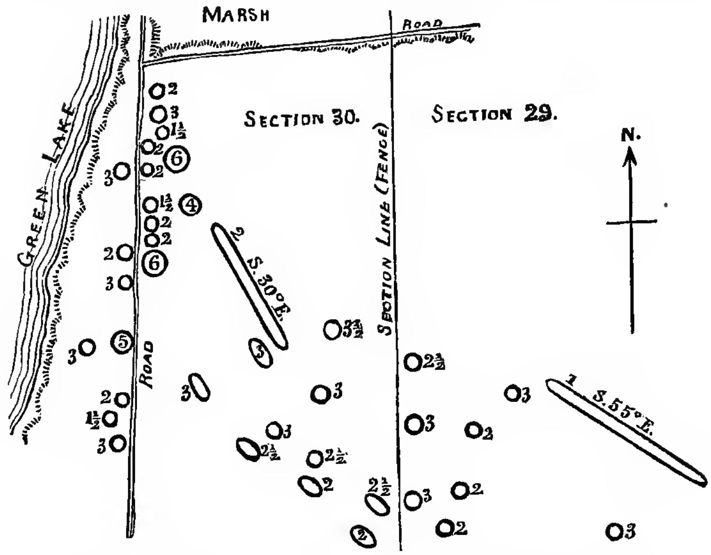


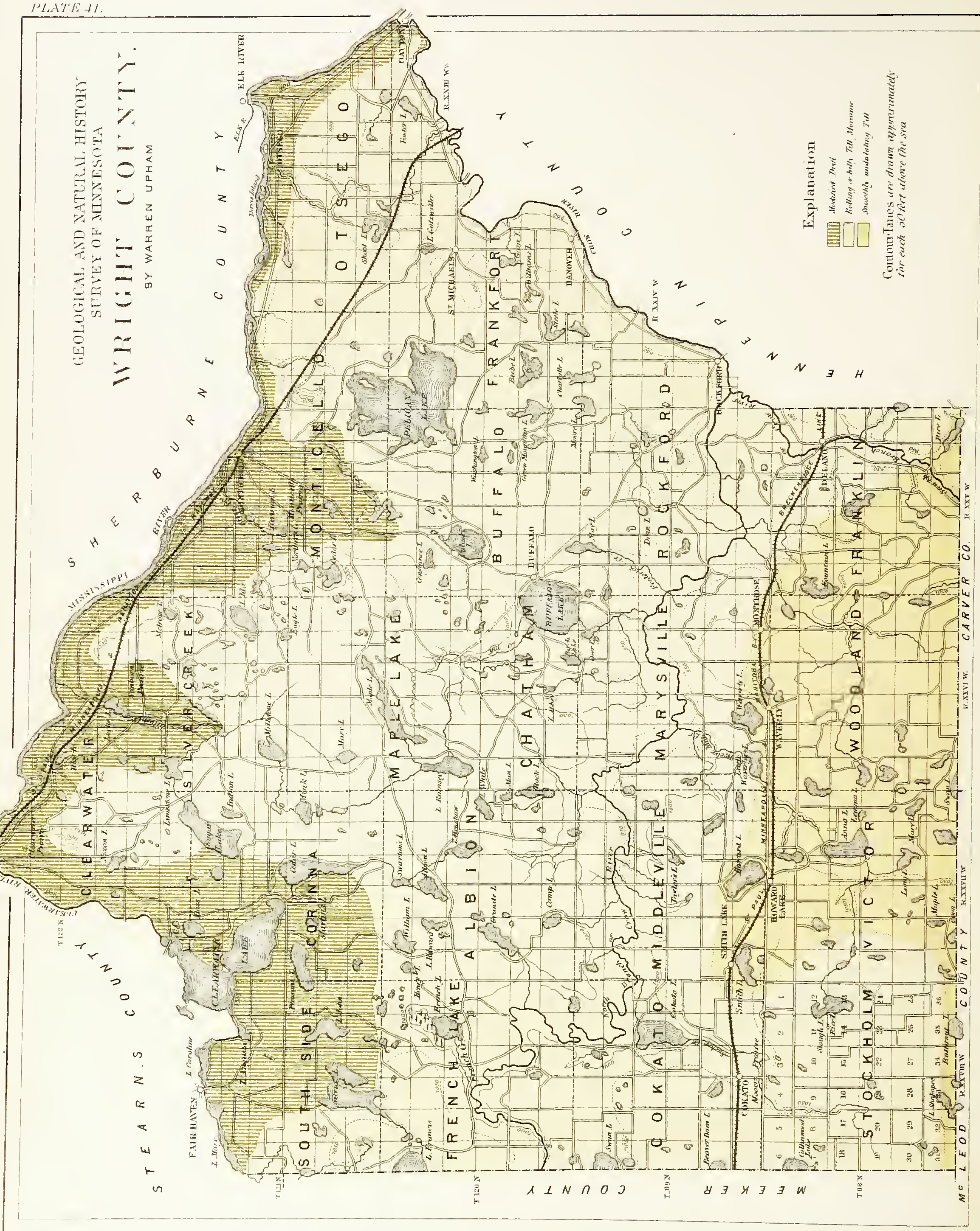
FIG. 15. MOUNDS AT EAST SIDE OF GREEN LAKE.
Scale, 12 rods to an inch.

mound marked with the hight of 5 feet has also been dug into, but it appears that no bones nor implements were found in either.

On the opposite side of Green lake, at Green Lake post-office, in New London, the black soil, two to three feet thick, constituting the upper part of the till, contains through its entire three feet occasional pieces of ornamented broken pottery, evidently of large vessels, which would hold one to two gallons; but no pieces more than five or six inches long have been found. This soil also contains plentiful bones and fragments of bones, partly of small rodents, and partly of larger animals, including some which appear to have been broken for the marrow, and numerous vertebræ of fish. These relics of aboriginal habitation are frequently found at this locality by Mr. Samuel H. Adams, in cultivating his garden, and in shallow digging as for posts.

No artificial mounds were noted in Meeker county.

PLATE 41.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
WRIGHT COUNTY.
BY WARREN UPHAM
Explanation
Contour lines are drawn approximately for each 50 feet above the sea
SHERBURNE COUNTY
HENNEPIN COUNTY
CARVER CO.
McLEOD COUNTY
MEEKER COUNTY
STEARNS COUNTY
MISSISSIPPI RIVER
CLEARWATER
SILVER CREEK
MONTICELLO
OTSEGO
FRANKFORT
BUFFALO
ROCKFORD
MAPLE LAKE
CHATHAM
MARYSVILLE
FRANKLIN
WOODLAND
CORINNA
SOUTH SIDE
ALBION
MIDDLEVILLE
FRENCH LAKE
COKATO
VICTOR
STOCKHOLM
Julius Bien & Co. lith.

CHAPTER X.

THE GEOLOGY OF WRIGHT COUNTY.

BY WARREN UPHAM.

Situation and area. Wright county (plate 41) lies on the southwest side of the Mississippi river between the Crow and Clearwater rivers. Dayton, situated at the mouth of the Crow river, partly in the east extremity of this county, and partly in Hennepin county, is 21 miles in a straight line northwest from Minneapolis and about 30 miles northwest from Saint Paul. Monticello, on the Mississippi river, 14 miles west-northwest from Dayton, is the oldest town in the county. Buffalo, on the northeast shore of Buffalo lake, near the centre of Wright county, 10 miles south-southwest from Monticello, is its county-seat. Other considerable towns and villages of this county are Otsego, on the Mississippi, six miles above Dayton; Clearwater, on the Mississippi at the mouth of the Clearwater river, in the northern extremity of the county; Fair Haven, lying partly in the edge of this county, on the Clearwater river about eleven miles southwest from its mouth; St. Michael's, in Frankfort, seven miles west of Dayton; Hanover, on the Crow river, about four miles south from the last; Rockford, fifteen miles southwest from Dayton, on the Crow river about a mile below the junction of its north and south branches; Delano, four miles southwest from Rockford, on the South branch of the Crow river where it is crossed by the Breckenridge line of the Saint Paul, Minneapolis & Manitoba railway; and, on this railway in its course westward through the south part of this county, Montrose, Waverly, Howard Lake, Smith Lake and Cokato.

The length of Wright county from east to west is 36 miles, and its greatest width is 30½ miles. Its southern and western boundaries are straight lines, the former 24 miles and the latter 22 miles long. This county includes fourteen whole townships of the governmental surveys and parts of eleven others, together constituting twenty organized townships, twelve of which are each six miles square. Its area is 713.97 square miles, or 456,939.32, acres, of which 32,585.50 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The North branch of the Crow river enters Wright county near the middle of its west side, and crosses the county in a very meandering course, which has its general direction a little to the south of east. The South branch flows northerly through Franklin, the most southeast township of this county, and unites with the North branch at the east side of Rockford township, sixteeen miles in a straight line southwest from the mouth of the Crow river at Dayton.

Clearwater river, along the last fifteen miles of its course, is the boundary of this county on the northwest. Near the middle of this distance it flows through Clearwater lake, four miles long and from a half mile to one and a half miles wide.

The only considerable tributaries of the Mississippi river from Wright county, besides the foregoing, are a small creek at Otsego; Otter creek, a mile above Monticello; and Silver creek, which flows through the township of this name. These, and the tributaries to Clearwater river, and the branches of Crow river in this county, are all small, only draining areas that reach five to twelve miles from their mouths.

Lakes. The largest lakes of this county are Pelican and Clearwater lakes, covering respectively about six and four square miles. Others worthy of note are Maple and French lakes, the former abont three miles and the latter one mile in length, which give their names to the townships in which they are situated; Pulaski lake in Buffalo, one and a half miles long from north to south; Buffalo lake, one and a half miles in diameter, lying mostly in Chatham; Waverly, Howard and Cokato lakes, each about one and a half miles long; Granite lake in Albion, of similar length; lake Ida and Limestone lake in Silver Creek, each about a mile long; Sugar and Cedar lakes, each two miles long from north to south, and Pleasant lake, one and a half miles long from east to west, in Corinna; and Sylvia lake, about two miles in length, nearly divided by a peninsula one mile long, in South Side. About ninety lakes occur in this county with a length equal to or greater than a half mile, and more than a hundred and fifty of less dimension appear on the map, while many others of small area are not delineated.

In many instances, especially in the southwest part of the county, these lakelets are becoming silted up and are more or less filled with marsh-grass, sometimes being nearly dry in summer. They thus show the various stages intermediate between a lake and a slough. Throughout the whole county, sloughs or marshes are also frequent, varying from a few rods to a half mile in length, and in some cases they extend one or two miles.

Wells usually obtain plenty of water, excellent in quality, at depths that vary from 20 to 50 feet.

It has been observed by the older residents that the streams and lakes were gradually diminishing in volume during the two decades of years preceding 1880. Several lakes were noted in my exploration, in 1879, between Buffalo and Crow river, depressed five [to seven feet below a high-water mark at which they had formerly stood. The three more rainy years from 1880 to 1882, inclusive, restored the lake and sloughs of this region generally to their highest stage.

Ice-formed ridges. Many of the lakes in this county, as likewise in most other parts of the state, are partially bordered by a ridge, heaped four to eight feet in hight, of gravel and sand, in which boulders, from two to five or six feet in diameter, frequently occur. This formation, when composed principally of gravel and sand, is commonly from 30 to 75 feet wide, having moderate slopes and a rounded top which varies a little in hight. Again, when consisting chiefly of coarse gravel or boulders, the ridge may be quite steep, sometimes sloping at an angle of forty-five degrees upon the side away from the lake. These accumulations are found mostly where lakes are bordered by lowland or a marsh, from which the water is divided by this low ridge, which often looks like an artificial rampart. The origin of these ridges is generally known to be from expansion of the ice upon the lakes in winter. Boulders lying in shallow water are frozen into the ice and pushed a very small distance each year toward the shore. This is repeated through centuries at the varying stages of the water, till the materials of these ridges, gathered from the lake-bed, have been piled along its margin. Such accumulations were noted at the east side of Dean lake in Rockford; at the north side of Buffalo lake; and about Howard lake, west of which the road runs about a half mile upon a ridge of this origin, five to six feet high and three rods wide, composed of gravel and sand, so ancient that it is covered with the same dark soil which generally forms the surface of this region.

The shores of the lakes of Wright county mostly have very gentle slopes, which are continued beneath the water's surface. The basin of Pelican lake is of this kind. Less frequently the shores have been worn away by the waves, and form bluffs 10 to 20 feet high. Examples of such erosion are seen on the northwest side of Buffalo lake. Here, and usually at the foot of similar banks beside lakes, a pavement of large and small boulders extends several feet above the water. About a mile west of Buffalo this margin of boulders, some of them six feet in diameter, lying at the foot of the bank undermined by the lake, is quite noticeable in comparison with the usual scarcity of such rock-fragments. Most of these were contained in the mass of till that has been washed away at this place. A few of them may have been added from the lake-bed by the expansion of ice, which has pushed back to the receding shore the boulders of the whole area upon which the lake has encroached, eroding its border of till.

Topography. Nearly all of Wright county is included in the morainic belt which extends from the Leaf hills south and southeast to this county and thence southward into Iowa, where it bends in a loop like the letter *U*, thence taking a northwestward course along the Coteau des Prairies in southwestern Minnesota and eastern Dakota. It has been elsewhere shown (vol I, page 406) that this long, looped moraine marks the sides and termination of a great lobe or tongue of the ice-sheet, and that it was contemporaneous with the Kettle moraine, which professors Chamberlin and Irving traced in a similar looped course across Wisconsin in the recent geological survey of that state.

These hills within the limits of Wright county seldom exhibit the singularly rough, broken, and irregular contour, which may be called the typical development of a terminal moraine. They yet are very different from the gently undulating, smooth area, a hundred miles wide, which lies next southwest, between this belt and the Coteau des Prairies. In contrast we find most parts of Wright county consisting of hills 40 to 75 and sometimes 100 or 150 feet high. These in nearly all cases have only moderate slopes, seldom rising abruptly or having a notably broken contour. No well-marked uniformity in trend is perceptible, though upon the average these elevations are more prolonged from north to south or northwest to southeast than in the opposite directions. In respect to material there is little difference between the swells and hills of this county, or even the more roughly outlined Leaf hills, and the smoothed, slightly undulating expanse that stretches southwest from this moraine to the Coteau, all being the unstratified glacial drift, called till or boulder-clay, inclosing or rarely overlain by comparatively small deposits of modified drift, that is, water-deposited gravel, sand, or clay. The till usually contains, however, a much greater proportion of boulders upon its morainic belts than on its smoother areas.

The most conspicuous hills seen in this county occur at two points near the Mississippi, about two miles south of Clearwater, and about the same distance southeast of Monticello. These rise 100 to 150 feet above the surrounding land. Another notably hilly area is the region for five miles northwest of Crow river, from its mouth to Rockford and Delano. These hills are more massive, but of less altitude than the foregoing, rising 75 to 125 feet above the river.

In the east part of Silver Creek township, a very rough area of till reaches north to the river-road in section 14, a mile southeast from the mouth of Silver creek. It forms hills 50 to 75 feet high, averaging 50 feet above the plains of modified drift at each side. The most uneven contour seen anywhere in Wright county was found in crossing this tract from Silver lake to lake Ida, where the surface is as rough and irregularly thrown up in a profusion of knolls, hillocks and ridges as it is commonly in the most broken portions of the most typical morainic deposits. These accumulations are coarsely rocky till, and apparently include but little modified drift. The course and trend of the elevations are very irregular, and no prevailing direction or parallelism is noticeable.

The contour about Buffalo is in gentle swells 50 to 75 feet high. These continue northwest and west through Maple Lake, Chatham and Albion, and southwest to Waverly and Howard Lake. These swells are round or irregular in form, trending in various directions. North of Cokato, massive, gently sloping hills rise 40 to 75 feet or rarely 100 feet above Cokato lake. The same rolling surface prevails northward through the west half of French Lake township, and also extends westward into Meeker county.

Stockholm, at the southwest corner of the county, and most of Victor the township next east, are moderately rolling, the hight of the swells decreasing from 30 or 40 feet at the west to only 10 or 20 feet at the east. From Smith Lake to Waverly the south boundary of the hilly area is on the north side of the railroad, and the tract beginning here and extending southeastward to the south line of the county, including the east part of Victor, Woodland, and the southwest part of Franklin, is only slightly undulating or nearly level. It is, however, mainly composed of till, like the hilly land northward.

With this exception, the only extensive level areas found in Wright county are those of modified drift which occur along the Clearwater and Mississippi rivers, consisting in large part, especially along the Mississippi, of natural prairies. The topography of these tracts, and the erosion which has been accomplished by the Mississippi river and its tributaries, will be again and more fully spoken of in describing the glacial and modified drift of this county.

Elevations, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

Clearwater line.

	Miles from Saint Paul.	Feet above the sea.
Crow river, water, 859; grade,	33.91	876
Summit, cutting 15 feet; grade,	40.57	985
Cedar street, Monticello, grade,	45.76	933
Summit, cutting 7 feet; grade,	53.47	1017
Silver creek, water, 966; grade,	54.79	975
Rice lake marsh, natural surface, 957; grade,	56.30	964
Rice creek, water, 956; grade,	57.04	966
Clearwater,	60.71	964
Clearwater river, water 940; grade,	60.99	964

Breckenridge line.

Delano,	39.93	928
South branch of Crow river, water, 910; grade,	40.01	928
Montrose,	46.68	994
Waverly,	49.23	999
Waverly lake, water,	49.23	947
Twelve Mile creek, water, 961; grade,	51.43	1000
Howard Lake, station,	54.57	1010
Smith Lake, station,	57.22	1054
Two miles farther west, grade,	59.22	1050
Sucker creek, water, 994; grade,	59.90	1017
Cokato,	60.64	1050
Cokato lake, water,		986

The hight of the Mississippi river along the northern boundary of this county, as determined by the United States engineer corps, under the direction of Capt. Charles J. Allen, is, at Clearwater, 938 feet above the sea; at the head of Bear island, about a mile east from the mouth of Silver creek, 924;

at Monticello, 893; at Elk River, 853; and at Dayton, 843 feet. The river-shore at Dayton is the lowest land of Wright county. Its highest land, in Middleville, Cokato, Stockholm, and Victor, its southwestern townships, and the tops of the prominent hills mentioned near Clearwater and Monticello, are about 1,100 feet above the sea. Crow river, at the junction of its north and south branches, has an elevation of about 900 feet; and the south branch of this river, where it enters Wright county, is approximately 915 feet above the sea. At the west line of the county, the hights, above the same level, of both the north branch of the Crow river and Clearwater river are estimated to be about 1,000 feet.

Estimates of the mean hights of the townships of this county are as follows: Otsego, 925 feet above the sea; Monticello, 960; Frankfort, 940; Buffalo, 975; Rockford, 940; Franklin, 960; Silver Creek, 1,000; Maple Lake, 1,020; Chatham, 1,000; Marysville, 975; Woodland, 1,010; Clearwater, 1,020; Corinna, 1,020; Albion, 1,025; Middleville, 1,000; Victor, 1,040; South Side, 1,030; French Lake, 1,025; Cokato, 1,040; and Stockholm, 1,075. From these figures, the average elevation of Wright county is found to be 1,000 feet, very nearly, above the sea.

Soil and timber. All portions of Wright county have a very fertile soil, blackened by decaying vegetation to a depth that varies from one to three feet. Fully nine-tenths of its whole area are adapted for cultivation, the only exceptions being the frequent sloughs, very steep knolls or hillocks which occur rarely, and the abrupt bluffs, 20 to 50 and rarely 75 or 100 feet high, which border the creeks and rivers and were formed by their erosion. The generally undulating and rolling surface has sufficient slopes to give excellent drainage. The water produced by snow-melting in spring is thus speedily carried off, permitting grain to be sown early; and damage by excessive rains is prevented. The rain-fall is usually quite uniformly distributed through the successive seasons of spring, summer, and autumn; and from it the somewhat porous soil, which is the glacial and modified drift, readily absorbs the moisture needed by growing crops. The water of wells and springs in this region is commonly charged with the carbonates of lime and magnesia dissolved from the drift through which it has filtered. Though this does not impair its excellence for drinking and cooking purposes, it is rendered less desirable than rain-water for use in washing with soap. The pulverized limestone in the drift, which thus makes the water that soaks through it hard, is one of the most useful elements of the soil for the production of the wheat, corn, oats, potatoes, and hay, which, with dairy products and stock, are the chief agricultural resources of this district.

The Big Woods cover nearly the whole of Wright county. The only exceptions to this, before its settlement and the consequent clearing away of much of the timber to make farms, were Clearwater prairie, three miles long and one to two miles wide; Sanborn's or Moody's prairie, in Silver Creek; Monticello prairie, six miles long and three miles wide, including the portion of this which is commonly called West prairie, lying northwest of Otter creek; small areas of modified drift in Otsego, all the foregoing being portions of the valley drift of the Mississippi; a few small tracts bordering Crow river, as Butler and McAlpine prairies; and Mooers' prairie, south of Cokato, three miles long and about a mile wide. The last-named prairies are undulating and in part even hilly, and consist mainly of till or unmodified drift. On Mooers' prairie the hills rise in moderate slopes, 30 to 60 feet high. To these tracts are also to be added the numerous small sloughs, covered by marsh-grass, valuable for hay, which are scattered here and there throughout the wooded area. Though the principal prairies of this county are modified drift, it is yet to be noted that considerable portions of this formation, bordering the Clearwater and Mississippi rivers at the north side of the county, are covered by a natural forest. This is the case with large tracts of modified drift adjoining Clear lake and reaching from it southwest to Sylvia lake and east to Sugar lake, as also with much of the northwest part of Silver Creek township.

At least nineteen-twentieths of this county are wooded or have only been recently cleared. The greater part of this area is thick and heavy timber. The two species of trees which are usually most plentiful and largest are the white or American elm and the bass. Next in the estimated order of abundance are bur oak, ironwood, red or slippery elm, white and black ash, box-elder, black oak, the American aspen or poplar, and the large-toothed aspen, generally common; sugar maple and red or soft maple, mostly occurring in groups; wild plum, black cherry, Juneberry, balsam, poplar, and willows, plentiful in many places; tamarack, common in swamps; hackberry, white oak, butternut, and canoe or paper birch, less frequent; bitternut, cottonwood, and red cedar, rare.

Among shrubs the most common species are hazel-nut, prickly ash, Virginian creeper, climbing bitter-sweet, frost grape, sumachs, meadow-sweet, choke cherry, thorn, wild roses, bush cranberry, black currant, prickly and smooth gooseberries, high blackberry, and black and red raspberries.

GEOLOGICAL STRUCTURE.

The only formation found in this county, which can be referred to a date older than the glacial period, consists of beds of sand and gravel, some layers of which have been cemented, apparently by the deposition of carbonate of lime from percolating water, so that they have become sandstone and conglomerate, nearly as compact and hard as the most indurated rocks. These were at first thought to be portions of the drift, cemented since their accumulation, but it seems possible that they may instead be Cretaceous, being perhaps of the same age with the Cretaceous sandstone that outcrops in the Minnesota valley, in Courtland, Nicollet county, eight and eleven miles southeast of New Ulm.

Two localities of this rock are exposed in Wright county, one being on the Crow river, and the other on its north branch. From the bridge east of St. Michael's, crossing the Crow river between Frankfort and Hassan, a conspicuous outcrop of it is seen in the left or northwest bank of the river, about twenty-five rods north of this bridge. The bank here is some twenty-five feet high, and the cemented layer is in place near its top, from which position pieces five to ten feet in extent have fallen down and lie at or below the river-shore. This stratum of sandrock is three to five feet thick, nearly horizontal, of gray color, and was seen well exposed at two points some twenty-five feet apart. It is made up mainly of sand, with abundant fine gravel-stones, seldom so large as a half inch in diameter, but sometimes one and a quarter inches in diameter. Its lower portion incloses a layer of dark, irony sand, one foot thick. The bank fifty feet farther west is thirty feet high, and appears to be composed wholly of stratified sand and gravel, having pebbles up to two or three inches in diameter. Three hundred feet east from the exposure of the sandrock or conglomerate, the bank or bluff of the river is fifty feet high, but exhibits no clear section. A well at the top of this bluff went 20 feet through "quicksand," then a foot or two through "an irony hardpan," then through "clay," to a total of 44 feet, where water was struck and rose immediately eight feet. This irony layer, which is partly black, is seen also in the adjoining bluff, and probably corresponds to the layer of dark, ferruginous sand in the conglomerate. The cemented stratum is more or less exposed along an extent of thirty or forty rods, having a slight dip eastward which carries it in this distance from the hight of 20 feet down to the river's edge. It has been somewhat quarried for use in underpinning. Numerous specimens collected near this place by Mr. C. L. Herrick, from other low outcrops of the same formation, in the southeast bank of the river south of the bridge, are rather fine, gray, quartzose sandstone, containing no intermixture of gravel.

Mr. Herrick reports the discovery of a second locality of this rock in section 8, Middleville, where its outcrop rises only two feet above the north branch of the Crow river. This is a gray sandrock, mostly made up of fine quartzose particles, the greater part of which are white or gray, while some appear to be dull red jasper. It contains also a small proportion of granitic and other pebbles, up to three-quarters of an inch, but mostly less than one-quarter of an inch, in diameter. This locality is about twenty-five miles west of that before described at the east side of Frankfort. No other exposures of this rock, or of any formation, excepting the ordinary deposits of the drift, were observed by Mr. Herrick in a boat journey along the North branch and the Crow river, from Forest City in Meeker county to the mouth of this stream at Dayton.

Glacial and modified drift. Wright county is covered to an undetermined depth, probably averaging more than a hundred feet, by drift. The sections exhibited by streams and wells prove this mantle of drift to be so deep that we may safely attribute the generally hilly surface to movements of the ice-sheet which spread its deposits in unequal thickness. It has been shown that this area was at the east border of a great segment of the ice-sheet, and these masses of drift pushed up into hills, inclosing frequent lakelets, are found to be part of a very extended series of similar or yet more irregularly hilly deposits, which were accumulated by the slow current of the ice along its fluctuating margin. By numerous short retreats and reädvances, these terminal deposits were spread over an area from twelve to twenty miles wide; but only very rarely in this county was the ice-front so long in one place or so loaded with drift as to heap up very abrupt and high, roughly-outlined hills, like those which make the most conspicuous parts of this formation.

The moraine occupies all this county, except the nearly level area of till southeast from Smith Lake and Waverly and the areas of valley drift along Clearwater river and the Mississippi. Its topographic features have already been sufficiently described. The material of which it is composed is mainly till, or a mixture of boulders, gravel, sand and clay, confusedly blended in one unstratified mass. The principal ingredient is always clay, or very finely pulverized rock, unctuous and tenacious, giving this deposit sufficient cohesion to remain as a vertical wall with little danger of falling during the process of excavation, as for a cellar or well. The proportion of rock-fragments is small, as compared with their usual abundance in the eastern states. Generally the till in New England contains twenty times as many rock-fragments as in Minnesota. Other names for this deposit are unmodified drift, boulder-clay, and hardpan.

In respect to color and hardness considerable difference is perceptible between the upper and lower parts of the till. To a depth that varies from 10 to 25 or 30 feet, it has a yellowish color, because its iron has been changed from the protoxide to hydrous sesquioxide or limonite, by weathering, that is, by exposure to the air and percolating water. At greater depths, the till of central and western Minnesota is dark and usually bluish. Its iron is mainly in protoxide combinations as silicate or carbonate, or it is in the form of pyrites. Further oxidation and hydration of this iron in the upper part of the till changes it to limonite, with a yellowish brown color that is very effective to impart its hue to the whole deposit, of which, however, it constitutes only a small percentage. When this disseminated ore of iron is deprived of the combined water, changing it from limonite to hematite, as occurs frequently in brick-burning, it imparts a deep red hue. In the more common cream-colored bricks of this region, the iron is usually present in as great amount, but, through the influence of carbonate of lime in the clay, is chemically combined as a silicate and has no important coloring effect. The difference in hue of the till appears thus to be brought about by causes operating since its accumulation, which are still sending this zone of chemical change farther below the surface.

The distinction in hardness between the upper and lower till seems, on the other hand, to be due to unlike conditions in its formation. Usually at the same depth with the change of color, a similarly sudden and equally definite change is noted in the hardness of the till, which below is much more compact and hard than above. Often the difference is such that the cost of excavating in the lower till is twice as great as in the upper till. This change is frequently fonnd very well-marked at an exact and definite line, which is believed to mark the top of the portion of the till which lay beneath the ice-sheet and was subjected to its immense pressure, while the upper till was contained in the ice-sheet and dropped loosely when this was melted away.* Because of the greater compactness and very impervious character of the lower till, the discoloration of weathering has been quite commonly limited to the upper till.

Fossiliferous beds inclosed in till have been observed at numerous places in Minnesota; but no examples of this are known in Wright county. The beds of stratified drift which occur beneath or inclosed between sheets of till, as described in the list of wells on a following page, may have been deposited like the valley drift along the Mississippi, that is, by the waters discharged from the melting of an ice-sheet, after which they have been covered by the till of a later glacial advance; or they may be the deposits of subglacial streams, during a period when this region was deeply buried by ice. The former explanation seems to be demanded by the thicker of these stratified beds under till, while the latter was probably true of many thin water-bearing veins of gravel and sand, which may be the tracks of subglacial torrents.

The boulders of the drift in Wright county are principally granite, syenite, and gneiss. Fragments of quartzyte, similar to that near New Ulm and referable to the Potsdam age, occur rarely. Boulders of magnesian limestone are so common that they are collected for lime-burning, perhaps making up a twentieth part of the rock-fragments that exceed one foot in diameter. This

* The more compact "lower till" was perhaps the product of an earlier glacial epoch, and was at that time accumulated in the same manner as the upper till. It may also be considered highly improbable that such an agent as a "subglacial torrent" could have existed in the wide nearly level expanse of Wright county, or at any place in central and western Minnesota. The stratified, inter-till beds referred to by Mr. Upham are likely to be of the nature of interglacial deposits.—N. H. W.

rock is a much more abundant ingredient of the gravel in the till and modified drift, and of the recent beach-formations of the lakes. The proportion of limestone pebbles at the northwest side of Howard lake and at the south side of French lake, is about one third of all. The largest boulder of this stone noted in my examination of Wright county was beside the road in or near the northwest quarter of section 17, French Lake. The amount exposed measured 7 by 4 by 1½ feet in dimensions, perhaps an equal amount being buried. The surface of this block showed a section of large gasteropod shell, probably a *Maclurea*, seven and a half inches in diameter. The source of this limestone, forming a part of the glacial drift which here has been transported from the northwest, is believed to be the formations that outcrop near Winnipeg in Manitoba and along the west side of lake Winnipeg.

Fragments of lignite, an imperfectly formed coal, have been often encountered in digging wells in this county, and in some places have been found in such abundance in the beds of streams as to excite the hope that workable beds of coal might be discovered by proper search. These pieces are from thin layers of lignite in beds of Cretaceous age, such as have been found at several points near Richmond in Stearns county, which borders this on the northwest, as also near Redwood Falls and Fort Ridgely, and on the Cottonwood river. Some of these lignite-bearing deposits have been plowed up by the ice-sheets and now form part of the glacial drift, in which, through all southwestern Minnesota, fragments of this coal occur sparingly, being usually only from one to three inches in diameter. A well or cellar sometimes yields a half dozen or more of such lumps, but oftener contains none or only one or two. None of the pieces found are of such dimension as to show that they were part of any thick coal-seam; and it appears very improbable, judging from the small quantity of coal thus occurring in the drift, and from the character of the Cretaceous beds which have been explored in the localities before mentioned, that any valuable deposits of this lignite exist in Minnesota. Respecting this and other Cretaceous contributions to the drift, Prof. Winchell writes on page 43 of his sixth annual report, as follows:

"Information having been received from Hon. William Pfænder of the existence of some evidences of coal in Wright county, an examination was made of the designated localities. On sec. 33, T. 119 N., R. 25 W., land of John Marth and Fred Wanderzee, along the north branch of Crow river, pieces of Cretaceous lignite have been found in considerable quantities; also, along a creek, sec. 25, T. 119 N., R. 26 W., on land of Joseph Plant. These are all flat pieces, exactly similar to what have been found in numerous other places, though perhaps more abundant. An examination was made in company with Mr.

John Marth, of Delano. The banks of the streams are composed entirely of drift, and largely of blue hardpan. The lignite was seen in the bed of the creek, having been most observed at or near fording places, where it was most likely to be brought to the surface and seen by passing travelers. At no point could any Cretaceous beds be seen *in situ*. Along the stream are numerous pieces of slate, or fissile shale, likewise derived from the Cretaceous, though here immediately from the hardpan drift. It is possible that Cretaceous beds would be struck below the drift, in sinking a shaft."

A very instructive section in the till is exposed in the right or east bank of the Crow river at Dayton, between the dam and the upper bridge. This section (fig. 16,) is about 500 feet long and from 35 to 50 feet high. On the left the till reaches to the surface and its upper one to two feet form the black soil, below which it has a yellowish color to a depth of 15 feet, and is then directly underlain by reddish gray till, except that a layer of coarse ferruginous gravel, one foot thick, intervenes at their junction. The same yellowish upper till is cut fifteen feet deep for the road at the north end of the upper bridge, about three hundred feet west from the northwest end of this section. There it shows in some portions an indistinct lamination, which was doubtless produced

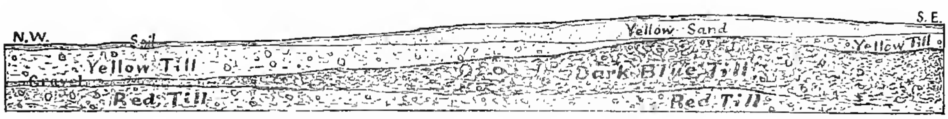


FIG. 16. SECTION IN THE DRIFT AT DAYTON.

in its deposition from the ice-sheet, probably through the influence of the water set free by its melting. Southeastward in the section here shown, the yellow upper till thins out to nothing in a distance of 300 feet. A little farther on, it is seen again and attains a thickness of ten feet near the southeast end of this section. For the first hundred feet at the northwest this till is covered only by the soil. Through the remainder of the section a layer of yellow sand, mostly from five to ten feet in thickness, overlies the yellow till. Next below this yellow upper till, throughout most of the section, is a deposit of dark bluish till, from 30 to 35 feet thick, like that which occurs generally throughout all southwestern Minnesota. Next below the last is the reddish gray till, which was noted at the northwest end of the section. There the thickness exposed of this lowest till is about 17 feet; elsewhere it is partly covered by the talus which has crumbled from the bank above; but at one place it was very plainly seen rising in a broadly rounded mass ten feet above the river-level. Professor Winchell has noticed this section on page 165 of his fifth annual report, and mentions that the blue till contains "many fragments of Cretaceous slate, siderite, iron concretions (covered with gravel and cemented r iron-rust), granitic pebbles, and (Devonian?) limestone masses which have pplied a great deal of quicklime, and an occasional large granite boulder." ıe underlying red till has "a great many small greenstone and quartzyte ɔnes, and but few that are large, also many granitic stones."

On the north side of the Mississippi river, one and a half miles west of ;sego village, and about seven miles northwest from Dayton, the river-bank, wly undermined along a distance of an eighth of a mile, having a hight of 50 60 feet, consists of red till for all its lower half, while its upper half is yellow ift. A few miles farther west, David Bagley's well, in section 16, in the east ge of Monticello township, found the following deposits of drift in descend- g order: soil and yellow till, 7 feet; sand, 12 feet; very hard, red till, 31 ɘt; and quicksand, 4 feet, in which the well stopped, at a total depth of 54 ɘt. Water is found in this quicksand, but does not rise above it.

Eastward from Monticello and Dayton, to the Saint Croix river, and to inneapolis and Saint Paul, the blue (or superficially yellow) till and the red l continued together, the latter underlying the former, which gradually thins t; and farther east, and northeast to lake Superior, only the red till is found. ıese deposits were quite fully described in the fifth annual report of this rvey, pages 156 to 174, and in the sixth report, pages 84 to 87. The con- ısion there announced is that the red till is the deposit of an earlier glacial och than the blue till which overlaps it. Another explanation is admissible d seems to be required by the distribution of these tills; for, while the red l covers the northeast part of this state and the most of Wisconsin, the blue l is found everywhere upon the western two-thirds of Minnesota and in Da- ta to the limit of the drift.

Climatic conditions can hardly be supposed to have existed which should capable of first producing an ice-sheet over the northeast part of the state ly, and afterward in another glacial epoch forming a similar ice-mantle spread ly upon the west half of the state. Professor Chamberlin, in his reports as ıte geologist of Wisconsin, demonstrated that the ice-sheet was partially ɹided at its front into vast tongues or lobes, each of which had its central cur- ıt in the course of its longer axis, while the marginal ice-flow was everywhere rpendicular toward its terminal edge. The presence of two such lobes of ɘ ice-sheet upon Minnesota is indicated by the course of our terminal mo- nes, and affords an adequate explanation of the occurrence of these diverse kinds of till in the northeast and the west parts of the state, as also of the portion of one of them overlying the other. The ice-lobe that moved outward from the region of lake Superior toward the southwest spread a till derived in large part from red shales, sandstones and quartzyte, colored by the anhydrous peroxide of iron, or hematite. The coloring power of this ore of iron, though it is only a proportionately small ingredient of these beds and of the drift, is sufficient to give a red or reddish gray hue to the drift wherever a considerable part of it has been obtained from this source, even when, being pulverized by the glacial grinding, it has become mingled with much material from other formations.

Western Minnesota was overspread by another ice-lobe, whose current moved from the region of lake Winnipeg to the south and southeast. Its drift was gathered from granitic and sedimentary rocks which have their iron mostly in protoxide combinations; and hence its color, below the weathered upper portion, is dark bluish.

During the last glacial epoch and perhaps in those preceding, it appears that these two lobes and opposing currents of the ice-sheet met upon the area lying between Dayton and Saint Paul. The current from the northeast reached to the farthest limit at which the red till occurs, which is in northeastern Wright county, if we except the few localities described in the report of Big Stone and Lac qui Parle counties, in the west part of this state and the east edge of Dakota. Afterward, a change of climatic conditions, probably by bringing an increased snow-fall at the northwest, caused the outflow of ice from that quarter to drive back the current opposed to it, until its blue till, derived from the northwest, had been spread over the edge of the red till. This overlapping of the drift deposits of the last glacial epoch, measured from west to east, that is, perpendicularly to the line of meeting of these currents, varies from twenty to seventy-five miles. The red and blue tills are regarded, in this view, as mainly contemporaneous and similar in their formation, the northeast and the west parts of the state being covered by lobes of the ice-sheet which moved independently of each other. When the ice of the last glacial epoch had its greatest extent, or nearly so, these ice-currents were confluent upon this area, the outflow from the northwest finally pushing back that from the northeast.

The erosion effected by the Mississippi river along the northeast side of Wright county has been mostly in the stratified gravel, sand and clay of the alley drift, which at the close of the glacial period was swept into this de-·ession by the floods discharged from the melting ice-sheet. A flood-plain as then accumulated which covered a width of five to ten miles or more, with ı average slope southeastward of about three feet per mile. It was deposited the same manner that additions are now being made to the bottomlands by ιe floods of spring, save that during the melting away of the ice-sheet similar gh water existed through the whole summer.* The flood-plain therefore pidly increased in depth and extent, the material of which it was formed as ell as the waters by which it was brought being both supplied from the eparting ice. Remnants of this plain, high above the present bottomland, test the great supply of sediment during the [prevalence and (N. H. W.)] ithdrawal of the last ice-sheet, and the large amount of erosion that has been complished since then by the river acting under its present conditions. At learwater and Monticello the prairies called by these names are remains of iis flood-plain, which extended with nearly equal hight across the area now cupied by the river and its bottomland, to the similar high plains of modified ·ift on the northeast side of the Mississippi. The areas of the ancient valley ·ift that occur in Wright county are situated like bays on the side of the main ılley, and have thus escaped excavation. The hight of Clearwater and Mon-ello prairies is about 75 or 80 feet above the river. Sanborn's prairie, lying etween these, is regarded as a part of the same descending plain of valley ·ift, though it is not bordered by equally distinct bluffs and terraces upon the le next to the river. This prairie and its adjoining wooded areas of modified ·ift are underlain at a small depth by till, the coarsely rocky boulder-clay or rdpan, which appears at the bridge across Silver creek on the river-road. ıe till rises so high along the river here that all of the overlying gravel and nd have been eroded. Where the modified drift extends deeper, it has been ulptured by the river in terraces and bluffs. Monticello village is situated such a terrace, 35 to 40 feet above the Mississippi, intermediate between the ttomland and the Monticello prairie.

In the distance from Clearwater to Dayton, the Mississippi descends 49 et. Its flood-plain of modified drift, deposited during the melting of the ice-eet, had a somewhat more rapid slope, declining in its hight southeastward 45 feet above the present river at Dayton, and to 25 or 30 feet at the head

* And save also that the normal size of the river was permanently immensely larger than now.—N. H. W.

of the falls of St. Anthony. On the northeast side of the Mississippi river, adjoining Wright county, the valley drift covers a wide tract, reaching beyond the Elk river, which for an extent of about thirty miles lies only two to five miles distant from the Mississippi, flowing nearly parallel with it.

Crow river and its north and south branches in this county have effected comparatively little erosion. At Dayton and in many other places along this river, it has undermined bluffs of till which extend from a few rods to a fourth or a half mile. A little more than a mile east of St. Michael's in Frankfort, this erosion shows a fresh section of till, 75 to 100 feet high, its upper 25 feet being yellowish and all below dark bluish. Such bluffs, however, are only of short extent, and in general this river has no definite line of continuous bluffs inclosing it on either side. Instead, the stream is bordered by undulating lowland, usually till, of varying width up to one mile, and rising in this distance to a hight from 30 to 50 feet above the river. Some portions of this valley have doubtless been filled with fluvial deposits at the close of the glacial period or since that time, bridging glacial hollows, which must otherwise produce lakes in the river's course, but with these exceptions no deposits of modified drift are found; so that this valley is very unlike that of the Mississippi, which was filled deeply with stratified gravel and sand.

Wells in Wright county.

Illustrations of these various drift deposits are afforded by the subjoined sections of wells.

Otsego. Hiram Harper; in the northwest corner of the township: well, 35 feet deep; soil, 2 feet; stony clay (till), 10 feet; stratified sand and gravel, 23 feet; no water. Another well on Mr. Harper's land, a third of a mile east from the foregoing, is 43 feet deep, its section being soil, 2 feet; till, 12 feet; sand with some gravel, 29 feet; water abundant, at first reddened by iron-rust, now clear.

Frankfort. Thomas Dean: 4½ miles southwest from Dayton: well, 33 feet; soil, 1½ feet; yellow till, 8½ feet; dark bluish till, twice as hard as that above, 23 feet; water rose from the bottom seven feet.

Buffalo. E. Richards; in section 20, some twenty feet above Pulaski lake: well, 27 feet; soil, 3 feet; yellow till, 10 feet; yellow gravel, 4 feet, with water in its lower part; harder dark clay (probably till) 6 feet; a ferruginous crust, one inch; and hard, apparently stratified, blue clay, 4 feet. The last layer contained a lump of cannel coal (lignite), about six inches in diameter, found twenty-five feet below the surface.

Franklin. The town well at Delano, 25 feet deep, went through yellow till, 20 feet; and dark bluish, much harder till, 5 feet; to gravel, from which water rose six feet.

The railroad well at Delano, 160 feet deep, is reported to have penetrated yellowish till, 25 feet; much harder, dark bluish till, 10 feet; quicksand, about 20 feet; and stratified gravel, sand and clay, for all the remaining depth; obtaining water, which rose a hundred and thirty feet, from gravel at the bottom.

Victor. J. H. Hobson; in the village of Howard Lake: well, 43 feet; yellow till, 14 feet; much harder gray till, 4 feet; gravel and sand with water, 2 feet; and soft, sticky, stony clay, probably unstratified till, 23 feet.

Joseph Boswell; also in Howard Lake: well, 32 feet; yellow till, 14; very hard, gray till, 8; quicksand, 10, with water rising above it four feet. Most of the wells in this village find the upper till, yellow and comparatively soft, 10 to 25 feet thick, abruptly succeeded below by dark bluish till, which is usually very compact and hard.

J. M. Corey; sec. 20: well at his house, 28 feet; yellow till, 24 feet; sand, with water, 2 feet; exceedingly hard, gray till, 2 feet and extending deeper. Another well at his barn, twelve rods south from the last and five feet lower, is 58 feet deep, being yellow till, 20 feet; sand, 1 foot, with water; yellow till, 2 feet; and harder, dark blue till, 25 feet; the auger is said to have then fallen four feet, and water rose immediately eighteen feet.

Middleville. At Smith Lake wells are 10 to 15 feet deep, finding yellow till, about 10 feet; then, gravel with water; succeeded below by very hard, dark bluish till.

Cokato. In the N. E. ¼ of sec. 20, some fifty feet above Cokato lake: well, 25 feet deep; soil, 2 feet; loose, yellow till, 5 feet; and very hard, blue till, 18 feet.

About one mile west of the last, at the northwest corner of the same section: well, 25 feet; yellowish till, 15 feet; soft, blue clay, easily shoveled, 10 feet.

Albion. At a house in the S. W. ¼ of sec. 10, about a quarter of a mile east of Albion post-office: well, 25 feet deep; soil and upper till or perhaps modified drift, 5 feet; white marl, very sticky when wet, yielding good lime by being moulded into blocks and burned, about one foot thick; till, yellow and comparatively soft, 19 feet, containing seams of sand one inch thick and from one to three feet long; to very hard, dark bluish till at 25 feet, which was not dug into. Another well, at the barn near the preceding, on land ten feet lower, is 14 feet deep; finding the upper five feet, and the succeeding layer of one foot of marl, the same as in the last; then, yellow till, 8 feet; to dark and very hard till at the bottom.

Other wells in Albion, Middleville, Chatham and Buffalo, 15 to 30 feet deep, are all till, yellowish and not difficult for excavation, apparently not reaching the lower till.

Silver Creek. Chester Dunklee; in sec. 15, about fifteen feet above Silver creek, which flows near by: well, 35 feet deep; soil, 2 feet; yellowish and then bluish till, very hard, picked, 20 feet; and stratified gravel and sand, 13 feet.

All the preceding show unmodified glacial drift or till, with which veins, and even thick beds, of stratified gravel and sand are often associated. The following are in the valley drift along the Mississippi and Clearwater rivers, and do not penetrate so deeply as to reach the till.

Monticello. Wells in the village are 25 to 35 feet deep, going through sand and fine gravel to coarse gravel at the bottom in which water is found. Two miles southeast from this village, Robert Schultz' well, 42 feet deep, going through gravel and sand, found at the bottom numerous fragments of lignite, also of wood, apparently red cedar, and remains of beetles (coleoptera).

Clearwater. W. W. Webster's store; in the village, on the bottom land, some 25 or 30 feet above the Mississippi river: well, 30 feet deep; soil, 2 feet; clay, 25 feet; sand, 3 feet. Other wells near show only 4 or 5 feet of clay, while some are all sand and gravel. At Mr. Webster's house, on a high terrace, about 70 feet above the Mississippi: well, 56 feet; soil and sand, 10 feet; gray clay, 18 feet; gravel and sand, 28 feet, with water at the bottom, fluctuating in hight the same as the mill-pond in Clearwater river.

South Side. Wells in the S. E. ¼ of sec. 23, and within one mile to the east and northeast, are 40 to 50 feet deep, being all gravel and sand, with no clay.

On Mr. Laton's farm, in sec. 34, a well 65 feet deep was as follows: soil, 2 feet; dark clay, growing reddish yellow below, 4 feet; coarse gravel, containing pebbles up to six inches in diameter, 2 feet; coarse, dark sand, becoming finer below, 9 feet; yellowish, coarse gravel, containing intermixed clay, hard, 1 foot; the same, but more sandy and less hard, 1 foot; grayish sand, suitable for mason's use, 12 feet; fine, white sand, 4 inches; yellowish and partly blue clay, iron-rusted below, 4 inches; gray, coarse quicksand, fine, below, 8 feet; coarse gravel, 1½ feet; light gray, fine sand, suitable for plastering, 7 feet; light gray clay, very hard, 8 inches; white sand, 4 inches; yellowish gray clay, about 1 inch; and gray sand, about 16 feet, to the bottom, its last foot being partly dark and rusty-colored, with water issuing from fine gray sand below.

This well encountered a much greater variety of deposits than is generally found in the modified drift. Its usual composition in this region is gravel and sand, with few or no layers of clay. The gravel differs in coarseness up to that which contains pebbles six inches or rarely one foot in diameter. The color of these beds of gravel and sand, through the entire depth penetrated by wells, is yellowish or gray. They are easily excavated, but because of their incoherent nature wells dug in them must be curbed during the work, being thus made nearly as expensive as in the till, which can maintain itself in a vertical bank.

MATERIAL RESOURCES.

The agricultural capabilities of Wright county, and its larger supply of timber, have already been noticed.

Water-powers utilized in this county are as follows:

Dayton flouring mill: on the Crow river at Dayton; owned by Weizel & Hurlbut; five runs of stone; head, about seven feet.

At Hanover: on the Crow river, about nine miles southwest from Dayton; head, about seven feet.

At Rockfort: on the Crow river; a woolen mill; head, eight feet.

In Middleville: two powers, on the north branch of the Crow river.

In Cokato: a grist-mill, at the mouth of Cokato lake, on its outlet.

In the west part of section 22, French Lake: a saw-mill on the north branch of the Crow river; head, eight feet.

Monticello mills: on Otter creek, three-quarters of a mile northwest from Monticello; owned by Janney & Sons; three runs of stone for flour, and one for feed; head, sixteen feet.

On the Clearwater river, at Clearwater, are three powers, as follows:

Thomas Tollington's saw-mill and furniture manufactory; ten or fifteen rods above the mouth of the river; head, five feet; can only be used when the Mississippi is at its low-water stage.

Clearwater flouring mills; a short distance above the last; owned by C. F. Davis & Co.; head, fifteen feet.

Upper dam of C. F. Davis & Co.; one mile above the mouth of the Clearwater river; known as the Fremont water-power; formerly, but not now, used; head twelve feet.

At Fair Haven: on the Clearwater river; head, about ten feet.

Building stone. In the absence of outcrops of rock older than the drift, the granitic and limestone boulders of the till are commonly used by the farmers, and to a considerable extent in the towns, for foundations, well curbing, culverts, and other masonry.

Explorations for coal. Professor Winchell, in his fifth annual report, for the year 1876, describes a former project for coal-mining, as follows: "Seventeen years ago there was some excitement in the vicinity of Dayton over a reported discovery of coal, about two miles west of the village, in Wright county, by a man named Charles Williams. Upon visiting the place, the excavation was found to consist of two shafts sunk in the drift, now nearly filled. About the place the drift thrown out shows nothing but drift clay with pebbles of all kinds and colors. One shaft is said to have been about eighty feet deep. The general belief now is that all the coal that was found was brought for the purpose from St. Paul, as the owner, after vainly attempting to sell his land, placed a heavy mortgage on it and abandoned the country, allowing the sale of the land for the mortgage. There is certainly now no evidence of the existence of coal, or lignite, in the vicinity, though there are traces of the Cretaceous in the drift which point to the near proximity of its layers. There is also a reported exposure of 'slate' in a ravine a mile or so beyond, but it could not be found." The occasional occurrence of fragments of lignite in the drift has been noticed on a preceding page.

Lime is burned from the magnesian limestone boulders in the drift by Levi Guier, at the north end of the upper bridge in Dayton. He has carried on this business eighteen years, formerly averaging from 800 to 900 barrels annually. His kiln holds 180 barrels, and is now emptied only about three times in a year, the market price having decreased within a few years from $1.50 to $1 per barrel. It is white lime, of excellent quality. Fossils are frequently noticed in the boulders of limestone gathered for this kiln; and one piece of it was presented for the museum by Mr. Guier, which is made up almost entirely of broken shells. Other kilns for lime-burning from these drift boulders have been worked in Otsego, Frankfort and Buffalo, as also probably in other parts of Wright county, but none were found in use at the time of taking these notes, in 1879 and 1881.

Bricks were first made in this county about the year 1855 by Lyman Dayton; and this work is still carried on at the same place, which is about a half mile west of Dayton, in the south edge of section 36, Otsego. It is a third or half mile distant from the two adjacent rivers, and some 40 feet above them. For several years, up to 1880, this yard was worked by Medor Arseno, with an annual product of about 250,000, selling at $7 to $8 per thousand. In 1881 it was leased for three years by Vassar & Co., who are making 300,000 yearly, selling at $8 per thousand in small lots at the kiln, or in large lots loaded on the cars at Itasca station, on the opposite side of the Mississippi. These bricks are mostly cream-colored, but near the outside of the kiln they are tinged with red. Sand is mixed with the clay for tempering in the proportion of one to six. An area of about two acres of stratified clay suited for brick-making is found here, lying in a depression of the till. The black soil, two feet thick, is stripped off, and the next 6 to 10 feet of clay is used. A thickness of 5 to 7 feet, next below the soil, is finely laminated, yellowish-gray clay, with here and there irony-stained or dark layers. Some portions of this clay are worthless for bricks because of limy concretions, but most of it is free from them. At a definite line the yellowish hue, which characterizes the upper part of this clay-bed, is succeeded by a dark bluish color. The lower part is further distinguished by requiring a large proportion of sand for bricks and by shrinking more in drying and burning. It contains many limy concretions, but no other pebbles. A well 29 feet deep at the brick-yard got no supply of water, and is said to have failed to reach the bottom of the dark clay.

Red bricks of good quality have been made since 1876 by Ingersoll Brothers, near the centre of section 13, Otsego. Their product in 1880 was 115,000, and in 1881, 140,000, selling for $8 per thousand at the kiln. This clay, which needs no admixture of sand, is the two to four feet next to the surface upon small morainic hillocks of till. All of it is slightly gravelly, but far less so than is usual in this formation. The convent and schools at Saint Michael's were built of bricks from this place.

A kiln of red bricks, used for the court-house at Buffalo, was made in 1876 on W. H. Cady's land, two miles northeast from that village.

Within a few years past, Frederick Zimmerman has made bricks a half mile west from Howard Lake station, but the business is now given up. More recently he has begun brick-making five miles north of Howard Lake, near the north branch of the Crow river, about a fourth of a mile northeast from Boam's bridge, in Middleville.

At Cokato brick-making was begun by James Runions in 1873. During the following six years he made on an average 300,000 yearly, selling at about $8 per thousand. The color is red. The quantity of workable clay here, extending over a half acre or so, is thought to be nearly exhausted. The section of a well at this brick-yard, close east of the main street and north of the railroad, is soil, 2 feet; yellowish gray clay, 2 feet; gravel and sand, 3 feet; yellowish "hardpan" (till), 12 feet; dark bluish till, said to be not quite so hard as the foregoing, 4 feet, and extending lower. Water came in veins in the dark till.

ABORIGINAL EARTHWORKS.

The artificial earthworks commonly denominated "Indian mounds," are found at numerous places throughout this region. At Dayton two large mounds are situated at the top of the bank which shows the section, before described, of red till under blue till. These mounds have the usual dome-like form. They are about forty feet in diameter and nearly ten feet high. There is another large mound on James Ream's land, two miles southwest from Dayton, on the north side of the Crow river.

Four miles south of Monticello, on William H. Hoar's farm, are several aboriginal mounds, of the same round form, but smaller, situated on a level prairie, within an area thirty or forty rods in extent. Two of them are each two rods across, and were originally four feet high; but their hight has been reduced by plowing to two and a half feet. From centre to centre of these is about sixty feet in a southwest direction. Some six hundred feet farther east is another mound, two-thirds as large. No bones nor other relics have been struck in plowing over them.

In the southeast part of section 8, Buffalo, on Thomas Smithson's farm, west of the north end of Pulaski lake, and two and a half miles southwest from the mounds last described, is another interesting group of aboriginal earthworks. Five mounds occur here in a row, which extends from north-northeast to south-southwest. The central and largest one measures fifty feet in diameter at the base, and is now eight feet high, but originally was fully ten feet high. Within a hundred feet to the north-northeast are two small mounds, twenty-five feet across, and two or three feet high; and within the same distance to the south-southwest are two others, similar to the last. They are about fifteen rods east of the road, on an area of gently undulating till, some 40 feet above the lake. A few years ago a party from Monticello dug through the largest of these mounds. Many skeletons, buried in a horizontal position, in two or more layers, one above another, were found; but it appears that no implements nor manufactured articles of any kind were discovered. At Mr. Hoar's, the mounds, situated on an area of modified drift, were surrounded by a shallow depression, perhaps six inches below the average surface; but at Mr. Smithson's this is not perceptible. About a sixth of a mile farther south, near Mr. Smithson's house, are four or five other small mounds.

CHAPTER XI.

THE GEOLOGY OF HENNEPIN COUNTY.

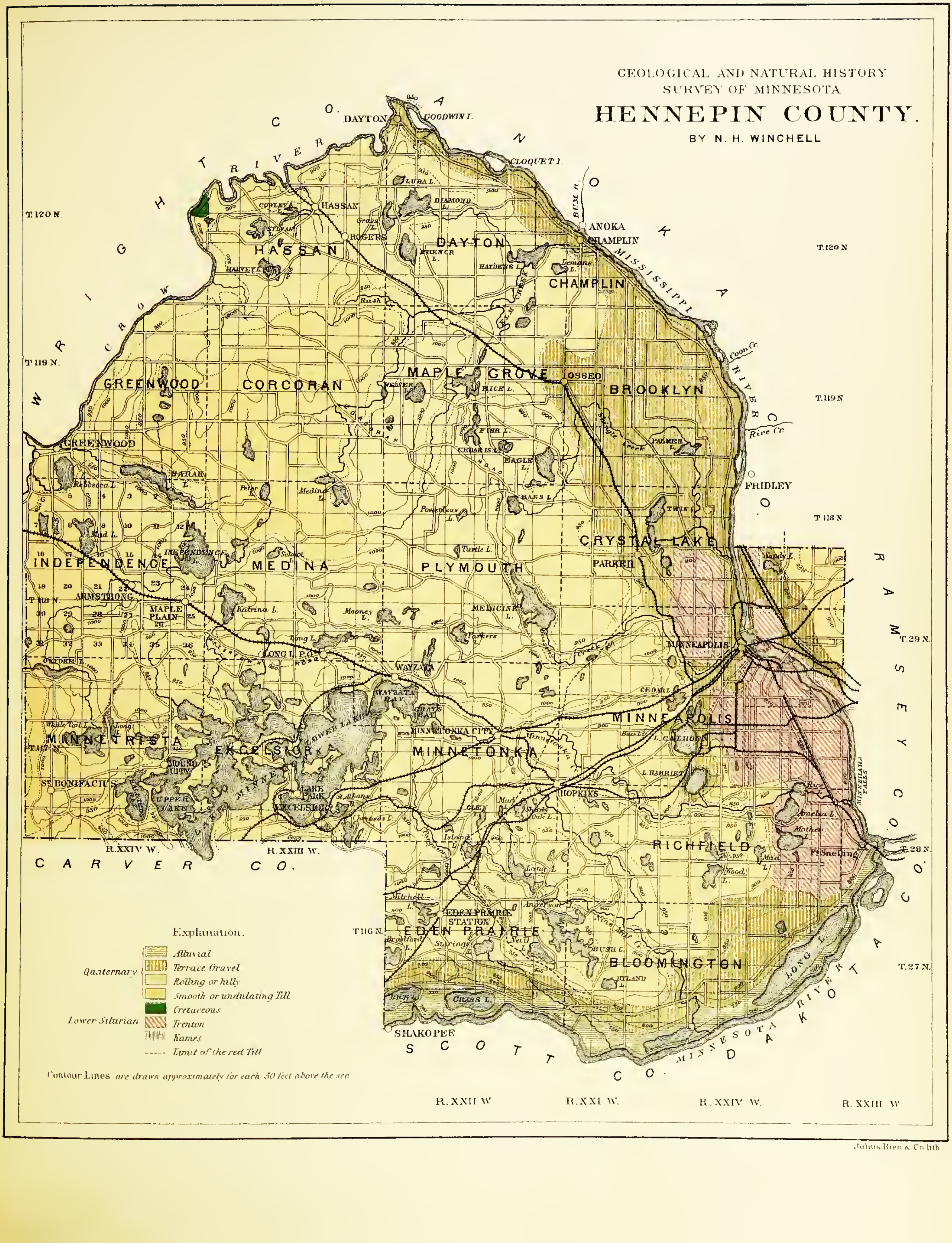
By N. H. WINCHELL.

Situation and area. As Dakota county is in the angle formed by the Minnesota and the Mississippi, below the point of their union, so Hennepin is in the supplementary angle formed by the same streams above the point of their union. It lies on the west side of the Mississippi, excepting the township of St. Anthony, which is on the east side, occupying the space between the Crow and the Minnesota rivers. It has a periphyry of over one hundred miles, of which about seventy-five are formed by water, and of which about fifty miles are navigable for steamboats such as ply on the upper Mississippi. Its extent north and south is about thirty miles, and from east to west about the same, but its shape is roughly orbicular, with a re-entrant angle at the southwestern side formed by the northeast corner of Carver county. Its total area amounts to 397,739.88 acres, of which 44,821.20 are covered by water, leaving 352,918.68 acres of land. Of this total area about 6,976.06 acres were estimated to be included in the United States reservation for Fort Snelling, this being at the apex of the angle between the Minnesota and Mississippi rivers, but the area of this reservation has since been considerably reduced, being now 1,531.20 acres.*

SURFACE FEATURES.

Natural drainage. The Mississippi river is along the northeast, the Min nesota along the south and southeast, and the Crow river runs along the north west. Several small streams flow from the central and southwestern portions outwardly in nearly all directions, but no large streams enter the county,

* Letter of Lieut. John Biddle, chief engineer, department of Dakota.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
HENNEPIN COUNTY.
BY N. H. WINCHELL
HASSAN
DAYTON
CHAMPLIN
GREENWOOD
CORCORAN
MAPLE GROVE
BROOKLYN
INDEPENDENCE
MEDINA
PLYMOUTH
CRYSTAL LAKE
MINNETRISTA
EXCELSIOR
MINNETONKA
MINNEAPOLIS
RICHFIELD
EDEN PRAIRIE
BLOOMINGTON
WRIGHT CO.
ANOKA CO.
RAMSEY CO.
CARVER CO.
SCOTT CO.
DAKOTA CO.
CROW RIVER
MISSISSIPPI RIVER
MINNESOTA RIVER
RUM R.
Explanation.
Quaternary
Alluvial
Terrace Gravel
Rolling or hilly
Smooth or undulating Till
Cretaceous
Lower Silurian
Trenton
Kames
Limit of the red Till
Contour Lines are drawn approximately for each 50 feet above the sea
R. XXIV W.
R. XXIII W.
R. XXII W.
R. XXI W.
T. 120 N.
T. 119 N.
T. 118 N.
T. 117 N.
T. 116 N.
T. 29 N.
T. 28 N.
T. 27 N.
Julius Bien & Co. lith.

except where the Mississippi intersects the city of Minneapolis. Scattered over the county are numerous lakes. Lake Minnetonka is near the centre of the county, one of its bays projecting into Carver county. This lake is an irregular expanse of water, lying on the drift deposits, with generally high knolls and gravelly beaches surrounding it. Its extent from east to west is twenty-three miles, and twelve miles from north to south. Its water is clear and in some places deep. It is a well-known and favorite summer resort. On its waters ply numerous small steamers. Its outlet is Minnehaha creek, which joins the Mississippi a short distance below Minneapolis.

Topography. The most of the county has an undulating or rolling drift surface, and a nearly level general contour. A belt of broken land enters the county from the east and southeast, and leaves it toward the northwest, crossing the Mississippi and the Crow rivers, and connecting, in the southern part of the county, with a similar tract on the opposite side of the Minnesota in the vicinity of Hamilton. Where these streams cross this area of rolling drift they have profoundly affected its composition and its general posé. They have carried away much of the transportable finer constituents, leaving in the adjoining knolls and ridges only the coarser elements, and they have flattened out the whole, over wide belts. This has not noticeably affected the average elevation, except within the immediate valleys so occupied by running water, since, at the time this effect was wrought, there was from all directions a movement of surface waters toward these valleys which not only supplied new material, but maintained the power of the erosive agent. Such modified drift surface is most noticeable along the Mississippi river above its junction with the Minnesota. It is seen on both sides of the river, the outer bluffs of the valley, where the less modified rolling drift surfaces begin, being separate from each other from three to six or seven miles. The immediate surface of these flat lands, originally in the state of prairie, or with sparse oak openings, is sandy or alluvial, with more or less admixture of humus, according to situation. But at the depth of two to four feet is found a coarser gravel and sand, the product of direct wash from the glacial ice, the equivalent of that found in the hills and knolls along the outer bluffs. Below this is uniformly a varying thickness of till, the equivalent of that found constituting the surface, at a greater distance east or west from the river, outside the valley, and free from the washing action of running water at the time of transport and deposition.

This flat land has all been covered by the waters of the Mississippi; but its surface undulates moderately, and in some places is from ten to forty feet higher than in others. This is due to the persistent remains of patches of coarse till which did not receive complete disintegration and assortment. Such an area of greater elevation is that occupied by the campus of the state university, where every deep excavation reveals a heavy deposit of unmodified till lying below the stratum of washed and modified sand and gravel, and rising to a greater hight than in the lower levels adjoining. Sometimes the till (or stony clay) knolls rise completely through the canopy of washed materials, and this is more frequent near the outer borders of the main valley. Sometimes the coarser washed materials are piled up in huge hills within the flat tract. Such hills and ridges of gravel are seen within the limits of Minneapolis. The most remarkable is that which runs along the southwest side of Central park. These are produced by exceptional conditions in the general movement and manner of deposit of the drift, and are explained more fully in that portion of this report relating to the drift proper. The Mississippi valley itself has no relation, as a causal agent, in their production. They exist in other parts of the county, away from the great valley. Some very large ones are seen a few miles west of Minneapolis in the townships of Minnetonka and Eden Prairie and elsewhere.

While the river valleys are accompanied generally by level tracts, the lakes are surrounded, almost without exception, by rough and hilly lands. This is remarkably so for some miles about lake Minnetonka in all directions. In the depressions lie the protæan arms of that lake and the numerous smaller lakes by which the central part of the county is distinguished. The hills are sometimes two hundred feet above the adjoining valleys, and apparently consist wholly of clay.

Description of the towns of Hennepin county.

TOWNS **27** AND **28**, RANGE **23**, W. OF 4TH PRINCIPAL MERIDIAN. (*Partly in Ramsey county.*) *E. parts of* RICHFIELD *and* MINNEAPOLIS. These embrace the bluffs of the Mississippi and Minnesota rivers south of the city of Minneapolis, and a narrow strip of level prairie land along the west side of those rivers above the point of their confluence not exceeding two miles in width. In the Minnesota valley there is a wide timbered bottomland, subject to overflow, but along the Mississippi the rock-bluffs rise sheer from the water to the hight of about a hundred and twenty-five feet.

TOWN **29**, RANGE **23**, W. OF 4TH PRINCIPAL MERIDIAN. (*Partly in Ramsey county.*) *E. part of* ST. ANTHONY. This is a belt of one mile wide, embracing six sections, and lies mostly on the east side of the Mississippi river. It is nearly all included within the prairie-land that characterizes the Mississippi valley, except about a mile square in its northern portion, which is rolling and wooded, and a narrow strip covering the eastern, outer-bluffs of the river, which is also rolling and wooded.

TOWN **27**, RANGE **24**, W. OF THE 4TH PRINCIPAL MERIDIAN. (*N. of the Minnesota.*) *E. part of*

BLOOMINGTON. By far the larger portion of this town is prairie, lying in the northeastern part. Along the southern side the bluffs of the Minnesota, rising about a hundred and twenty-five feet, are not rocky, but consist of gravel, with a good surface soil and sub-soil, usually turfed and frequently timbered. The bottom-lands sometimes embrace large water-areas, and are very wide, the bluffs running from one-half mile to a mile from the river channel. The timber generally is light, except a small area in the northwest corner of the town. The town has several small lakes in the uplands.

TOWN **28,** RANGE **24,** W. OF THE 4TH PRINCIPAL MERIDIAN. *Central part of* RICHFIELD, *and southern part of* MINNEAPOLIS. The central and northern portions of this town are rolling, and contain numerous lakes, such as Wood, Grass, Mother, Amelia, Calhoun, Harriet, Diamond, Pearl, Rice, Duck, Mud. This rolling tract is crossed by Minnehaha creek. Toward the northeast and the southeast are patches of level prairie.

TOWN **29,** RANGE **24,** W. OF 4TH PRINCIPAL MERIDIAN. *E. part of* MINNEAPOLIS *township and the northwest part of* ST. ANTHONY. This town embraces the city of Minneapolis, on both sides of the river, and the falls of St. Anthony. The largest part of the town is flat, and the southeastern portion contains considerable prairie, particularly on the west side of the river, within the ancient drift bluffs of the river. The western portions, and a small area in secs. 1 and 12 are rolling and timbered, with lakes. There are also small areas of swamp, the largest being east of the Mississippi river in secs. 12, 13 and 24. Bassett's creek breaks the surface in the central part of the town on the west side of the river, entering the Mississippi about a mile above the falls.

TOWNS **115** AND **116** N. RANGE **21,** W. OF 5TH PRINCIPAL MERIDIAN. (*Fractional.*) *W. part of* BLOOMINGTON *and S. W. part of* RICHFIELD. This embraces a little prairie tract in the southern portion and several lakes in the northern, but it is mostly undulating and timbered. The Minnesota bluffs intersect the southern portion, but they are not rocky. They rise about 150 feet above the river. In the northern portion are some high drift knolls. Anderson lake is the principal body of water.

TOWNS **117** AND **118,** RANGE **21,** W. OF THE 5TH PRINCIPAL MERIDIAN. (*Fractional.*) CRYSTAL LAKE, *with parts of* MINNEAPOLIS *and* RICHFIELD. This is entirely a wooded and undulating or rolling tract, running N. and S. about two and a half miles wide, and east to the Mississippi north of Minneapolis. It has small marshy areas and one irregular patch of natural prairie northwest of Minneapolis city.

TOWN **119** N. RANGE **21,** W. OF THE 5TH PRINCIPAL MERIDIAN. (*The northeastern corner is in Anoka county.*) BROOKLYN. This town is altogether flat, except in the southwest corner, and is mainly one of prairie. The scattered timber is small. Palmer lake is in sec. 26, and through it runs Shingle creek, which is accompanied by some marsh. The Mississippi river forms the eastern boundary, but the bluffs are low, and consist of drift only. A belt of heavy timber skirts the river in the northeastern portion of the town.

TOWN **120** N. RANGE **21,** W. OF THE 5TH PRINCIPAL MERIDIAN. (*The most of this town is in Anoka county on the east side of the Mississippi.*) *E. part of* CHAMPLIN. This is a small area lying on the Mississippi river, having a variety of surface, flat prairie, timbered bottom-land, and lightly timbered upland.

TOWN **116** N. RANGE **22,** W. OF THE 5TH PRINCIPAL MERIDIAN. (*A small portion of this town is in Scott county, south of the Minnesota.*) EDEN PRAIRIE. While this town is mainly rolling or hilly, with lakes and some marshes, and liberally timbered, it took its name from a flat prairie which lies in the southern portion, bordering on the Minnesota river, including the bottom-land and a belt about a mile wide north of the bluffs. Purgatory creek, which runs southward through this town, uniting with the Mississippi in sec. 36, occupies a broad, deep valley, which has once served as an important drainage course. Several scenes of great picturesque beauty are obtainable from some of the hills overlooking this valley.

TOWN **117,** RANGE **22,** W. OF THE 5TH PRINCIPAL MERIDIAN. MINNETONKA. This town is wholly wooded and rolling, some parts being hilly. The morainic ridges are high and frequent in the southwest quarter of the town, through which also runs the valley of Purgatory creek. The highest source of this creek is in a marsh nearly on a level with lake Minnetonka, through which also flows Minnehaha creek. It is certain that a former discharge from Minnetonka lake was through this valley, and that but little change in the drainage courses at the outlet would cause it to return to that valley. The valley of Purgatory creek is broader and deeper than that of Minnehaha creek. This town also has small areas of marsh, intervening between the drift hills, and occasional lakes, the largest body of water being a part of Minnetonka lake, from which flows Minnehaha creek, crossing the centre of the town eastwardly.

TOWN **118** N. RANGE **22,** W. OF THE 5TH PRINCIPAL MERIDIAN. PLYMOUTH. This is also a rolling and timbered town, with several lakes and tamarack swamps. Medicine lake, in the southeast corner, is the largest body of water. From it flows Bassett's creek.

TOWN **119** N. RANGE **22**, W. OF THE 5TH PRINCIPAL MERIDIAN. MAPLE GROVE. This town is entirely rolling and wooded except a small portion in secs. 1, 12 and 13, which is an extension of the Brooklyn prairie. It is crossed by a small creek running north through the centre, and by a tributary of the same creek through the northwest quarter, the two uniting at the north line of the town. It contains several fine lakes, of which Eagle lake, in the southeastern corner, is the source of Shingle creek, which joins the Mississippi river near the north line of Minneapolis.

TOWN **120** N. RANGE **22**, W. OF THE 5TH PRINCIPAL MERIDIAN. (*Partly in Anoka county.*) DAYTON, *and the west part of* CHAMPLIN. This town resembles the last, but borders on the Mississippi river which has drift banks that rise about a hundred feet above the river. Crow river also touches it on the north. Within these drift banks is a lower, sandy terrace-level, comprising, however, a narrow strip compared with the terrace-flats further south, or with that at the same place on the opposite side of the river.

TOWN **117** N. RANGE **23**, W. OF THE 5TH PRINCIPAL MERIDIAN. EXCELSIOR *and parts of* MEDINA *and* MINNETONKA. About one half of this town is covered by water, pertaining to lake Minnetonka. The rest is rolling or hilly, and heavily timbered, with occasional smaller lakes and marshes. Along the south side of lake Minnetonka the drift hills are remarkably developed, in the region south and southeast from Excelsior, extending into Carver county. These hills consist of gray till, with a finer, less stony clay over the immediate surface.

TOWN **118** N. RANGE **23**, W. OF THE 5TH PRINCIPAL MERIDIAN. *N. part of* MEDINA. This town is much diversified with lakes, marshes and a rolling surface. It is entirely wooded. The northwestern part is much less rolling, some of it being quite flat.

TOWN **119** N. RANGE **23**, W. OF THE 5TH PRINCIPAL MERIDIAN. CORCORAN. The flat or undulating tract which begins in northwestern Medina expands northwardly so as to include the most of this town. The lakes are less numerous, and the timber is heavy. There are low, broad ridges of more stony clay that rise from three to thirty feet above the generally flat surface, sufficient to afford good drainage to the town. The surface is clay.

TOWN **120** N. RANGES **23** AND **24**, W. OF THE 5TH PRINCIPAL MERIDIAN. (*South of Crow river, the rest of these towns being in Wright county.*) HASSAN. This is wooded and more rolling than the most of Corcoran, having Crow river along its northern boundary. It also has numerous lakes which add to the variety of scene and topography. Soil and subsoil gravelly clay.

TOWN **117** N. RANGE **24**, W. OF THE 5TH PRINCIPAL MERIDIAN. MINNETRISTA. This town, like most of the country about lake Minnetonka, is greatly diversified with hill and valley in the western and central portions. It becomes more uniformly undulating in the northwest. Clay soil and subsoil; heavily timbered.

TOWN **118** N. RANGE **24**, W. OF THE 5TH PRINCIPAL MERIDIAN. (*A small part of section six is in Wright county.*) INDEPENDENCE. This is a rolling timbered town, dotted with small marshes and lakes. Soil generally clay, but sometimes sandy.

TOWN **119** N. RANGE **24**, W. OF THE 5TH PRINCIPAL MERIDIAN. (*Southeast of the Crow river; partly in Wright county.*) GREENWOOD. This town is undulating, or rolling, along the Crow river, but it becomes more monotonous, resembling Corcoran, in the central and southeastern portion, with considerable marshy land; heavily timbered.

[NOTE.—In the foregoing descriptions when any town is said to be timbered it refers to the original native condition. In nearly all these timbered towns extensive clearings have been made for farms.]

Elevations. The highest part of the county is in the north-central and western portions including the rough country about lake Minnetonka, on all sides except the eastern, the southeastern part of Independence, much of Medina, Plymouth, Corcoran and Hassan. These townships embrace some elevations that approach nearly eleven hundred feet above the sea, but the highest measured point is about a quarter of a mile east of Maple Plain, where the natural surface, according to the engineers of the St. Paul, Minneapolis and Manitoba railway, is 1,026 feet above the level of the sea. The Mississippi river, at Dayton, is 843 feet at low water; at Nicollet island, Minneapolis, 802 feet; at the falls, 800; at half a mile below St. Anthony falls, 720; at the mouth of the Minnesota, 688. At high-water stage the Minnesota river reaches 710 feet, at its union with the Mississippi.

The following railroad elevations can be given for this county.

On the St. Paul, Minneapolis and Manitoba railroad.

From the records in the office of the chief engineer.

Main line.	Miles from St. Paul.	Feet above the sea.
Crossing of the St. Paul and Duluth R'y, near St. Anthony Junction,	9.7	835
Junction at St. Anthony (Minneapolis N. E.),	9.8	842
E. Minneapolis (old station),	10.5	837
Mississippi river (low water), at the crossing at Nicollet island,	10.6	802
Minneapolis station (Minneapolis N.),	10.8	834
Cedar lake (water, 862),	14.25	867
Victoria lake (water, 900),	18.23	909
St. Albans,	21.23	927
Wayzata,	25.13	936
Lake Minnetonka (water level),		928
Long Lake station,	27.93	954
Maple Plain (cut 7 feet),	33.22	1023
Maple Plain (natural surface ¼ mile E.),		1026
Crow river crossing,	40	928
Delano (Wright county),	40	928

Osseo Branch.	Miles from St. Paul.	Feet above the sea.
Junction of the Osseo Branch,	12.05	822.40
Parker,	17.16	884
Shingle creek (water, 871; bottom, 868),	21.8	882
Osseo,	23.76	892
Elm creek (water, 878; bottom, 875),	26.2	885
Rush creek (water 906; bottom, 902),	28.7	926
Maple Grove station,		947
Hassan,	34.03	977
Crow river (water, 859; bottom, 856),	35.26	876

Elevations on the Minneapolis and St. Louis railway.

Furnished by Col. J. B. Clough.

	Miles from Minneapolis.	Feet above the sea.
Minneapolis and St. Louis depot, cor. 2d street S. and 4th avenue,		828
Crossing of Hennepin avenue, foot of Bridge street at the old suspension bridge,		815
Minneapolis depot (N. Minneapolis),		833
Cedar lake (water, 864),	2	867
[The line to Cedar lake follows the valley of Bassett's creek.]		
Bass lake (water, 880),	3.25	888
Divide between Bass lake and Minnehaha creek (natural surface, 932),	5.25	920
Marsh at Minnehaha creek (water, 892),	7.5	897
Minnehaha creek (water, 897),	7.8	909
Divide east of Hopkins (cut, 14 feet),	8.2	930
Hopkins,	8.7	921
Divide between Hopkins and Shady Oak lake (cut, 18 feet),	9.5	913

	Miles from Minneapolis.	Feet above the sea.
Shady Oak lake (water, 910),	10.6	912
[Piles were here driven 78 feet, to a hard bottom, which now supports the track; water, 20 feet; the rest mud, "or something else." Soundings at first indicated but 20 feet of water; but in filling, the bank settled at least 40 feet further; after two months' work at filling, with little visible progress, the builders had to resort to pile-driving.]		
Mud lake (water, 902),	11.1	905
[Rolling surface.]		
Divide between Mud lake and Glen lake marsh (cut, 8 feet),	11.3	925
Glen lake marsh (water, 907),	11.5	910
[At Glen lake marsh, after the track was built it sank, and was entirely lost, a lake being formed. Then piles were resorted to, with a depth of 50 feet, for a distance of 250 feet.]		
Divide 1000 feet west of Glen lake marsh (cut, 18 feet),	11.6	920

[Rolling descent to—]	Miles from Minneapolis.	Feet above the sea.
Island lake (water, 893),	12.7	905
Divide 1000 feet west of Island lake (no cut),	12.8	915
[On the east side of the line hills rise 75 or 100 feet higher, the road running through a gap; on the west side hills rise 30 or 40 feet. At 1500 feet further south the road passed through a ridge of gravel and red clay (mixed) in which was found a piece of native copper weighing 78 pounds. This was a cut of 30 feet.]		
Purgatory creek (bottom, 832),	14	856
[Piles were driven here 36 feet without finding a hard bottom.]		
Eden Prairie (cut, 8 feet),	15.2	885
Divide between Eden Prairie and Bradford lake (cut, 8 feet),	16.5	903
Bradford lake (water, 867),	17.7	875
Carver county line (natural surface, 907),	18.2	877

Pacific division of the Minneapolis and St. Louis railway.

From profiles in the office of Robert Angst, chief engineer, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
Hopkins,	8.7	921
Minnetonka mills,	11.7	936
Tamarack marsh (bottom, 880),	14.5	909
Hotel St. Louis (on the shore of Minnetonka lake),	15.8	943
Carson's bay (water, 928),	16	933
Solberg point,	17.9	938
Excelsior,	18.9	947
Centennial House (Victoria, Carver county),	25	936
Waconia (Carver county),	31.5	986

Chicago, Milwaukee and St. Paul railway.

	Feet above the sea.
Crossing of the Minnesota river, at Fort Snelling (bottom, 671.6)	717.48
Crossing of the Minnesota river, at Fort Snelling, low water,	688
Fort Snelling station,	721.50
Minnehaha station,	811.80
Minnehaha creek (bottom, 801.1),	815.20
Minneapolis depot, on Washington avenue,	825

The Hastings and Dakota division of the Chicago, Milwaukee and St. Paul railway.

From records in the office of M. D. Rhame, engineer, Minneapolis.

	Miles from Minneapolis depot.	Feet above the sea.
Minneapolis (depot on Washington avenue S.)		825
Short-line Junction (south Minneapolis),	1.8	843.66
Crossing of Cedar avenue (grade of the street, 865.66),	2.3	859.66
Crossing of Chicago avenue,	2.9	864.66
Crossing of Portland avenue,	3.2	866.16
Crossing of Nicollet avenue,	3.7	873.36
Crossing of Lyndale avenue,	4.2	878.66
Crossing of Hennepin avenue,	4.8	879.66
Long,	5.3	860.91
Cut of eighteen feet,	5.8	876.66
Bass lake (water, 879.66)	6.9	885.66
Summit,	8	918.66
Marsh (level of marsh, 890.66),	8.4	900.66
Hopkins station,	8.8	912.66
Crossing of spur track of Minneapolis and St. Louis railway,	8.9	911.66
Minnehaha creek,	9	911.66
Hopkins,	10.1	922.66
Davis creek,	11.1	900.66
Shady Oak lake (water, 906.66),	12	910.66
Foot of Mud lake (water, 904.66),	12.6	909.66
Crossing of the Minneapolis and St. Louis railway,	13	922.66
Island lake (water, 893.66),	14.5	898.66
Purgatory creek (bottom, 839.66),	15.3	901.66
Duck lake (water, 911.66),	15.7	921.66
Chanhassen (Carver county),	18.2	967.16

Chicago, Milwaukee and St. Paul railway. Short-line.

	Miles from St. Paul Union depot.	Feet above the sea.
Hennepin county line, N. E. ¼ section 31, St. Anthony,	7	849.66
Top of the rock bluff, east bank of the Mississippi,	7.3	800.66
Crossing of the Mississippi (low water, 710.66; high water, 725.86),	7.3	844.66
Minnehaha avenue, Minneapolis,	8.8	834.66
Short-line Junction,	9	843.66
Minneapolis (depot on Washington avenue),	10	825

Elevations on the St. Paul and Northern Pacific railway.

From profiles in the office of Chief Engineer J. W. Kendrick, Minneapolis; reduced through the datum established for the city of St. Paul, 693 feet above the sea.

	Miles from St. Paul	Feet above the sea.
Crossing of the Ramsey county line,	8.4	885.64
Mary street (edge of the drift bluff),	8.6	856.64
Crossing of the Chicago, Milwaukee and St. Paul railway (spur),	9.2	827.64
Universitv avenue (Minneapolis, S. E.),	9.4	827.64
[The cut along Arlington street descends from 827.64 to 815.64.]		
Crossing of Church street,		822.64
Crossing of State street		818.64
Crossing of Pleasant street,	9.6	816.14
Mississippi river (low water, 720.64; bottom, 719.64),*	10	815.64

*At this crossing of the Mississippi river the top of the limestone ledge, on the east side of the river, is 789.64 feet above the sea, and on the west side 787.64. This is not owing to a dip in the formation but to more denudation on the west side. On the east side the rock rises in the form of shales and thin limestone slabs, more or less disturbed, several feet above the level of the bridge. The top of the sandstone is about level, being 759.64 feet above the sea, on each side of the river.

	Miles from St. Paul.	Feet above the sea.
[The University campus, at the crossing of Pleasant street, is approximately 848 feet above sea.]		
Crossing of Nineteenth avenue (Minneapolis S.),		812.64
Crossing of Bluff street (Minneapolis S.),		811.64
Crossing of Cedar avenue (Minneapolis S.),	10.4	810.64
Crossing of Tenth avenue (natural surface,) (Minneapolis S.),		815.64
Crossing of Sixth avenue (natural surface,) (Minneapolis S.),	11	
Depot of the St. Paul, Minneapolis and Manitoba railway,	11.4	813.14
Crossing of Hennepin avenue (natural surface),	11.4	831.64
Crossing of First avenue N. (street, 836.64),		817.64
Crossing of First street N. (street, 841.64),		824.64
Crossing of Fourth avenue N. (street, 846.64),	11.9	825.64

Line B, of the St. Paul and Northern Pacific railway.

(Running through East Minneapolis.)

	Miles from St. Paul.	Feet above the sea.
Bayless avenue, in St. Anthony Park,		903.64
Last cut in the bluffs (cut 24 feet),		890.64
Crossing of Como avenue,	9.3	858.64
Crossing of Division street,	9.7	856.64
Crossing of the St. Paul and Duluth railway,		850.64
Crossing of Fillmore street,	10.7	849.64
Crossing of Harrison street,		848.64
Crossing of Monroe street,	11.3	841.64
Crossing of Twenty-third avenue (N. E.),	11.6	849.64
Crossing of Twenty-fourth avenue (N. E.),	11.8	850.64
Mississippi river (low water, 794.64; high water, 803.64),	13.2	825.64

Elevations on the Minneapolis, Lyndale and Minnetonka railway.

From the profiles in the office of Geo. W. Cooley.

	Miles from Bridge Square.	Feet above the sea.
First street, Bridge square,		837.5
Second street,		838
Crossing of Washington avenue,		842
Crossing of Third street,		840
Crossing of Fourth street,		847
Crossing of Fifth street,		850
Crossing of Sixth street,		854.5
Crossing of Seventh street,		852
Crossing of Eighth street,		852
Crossing of Ninth street,	.54	844.5
Crossing of Tenth street,		850
Crossing of Eleventh street,		850.05
Crossing of Twelfth street,		854
Crossing of Thirteenth street and First avenue S.,	.86	852
Crossing of Thirteenth street and Nicollet avenue,		847
Crossing of Grant street,	1.02	841
Crossing of Fourteenth street,		844
Crossing of Fifteenth street,		849
Crossing of Sixteenth street,		852
Crossing of Seventeenth street,		854.5
Crossing of Eighteenth street,		863.5
Crossing of Nineteenth street,		867

	Miles from Bridge Square.	Feet above the sea.
Crossing of Franklin avenue (or Twentieth street),	1.52	878.5
Crossing of Twenty-second street,		897
Crossing of Twenty-fourth street,		895
Crossing of Twenty-fifth street,		888
Crossing of Twenty-sixth street,		874
Crossing of Twenty-seventh street,		871
Crossing of Twenty-eighth street,	2.26	872
Crossing of Twenty-ninth street,		873
Crossing of Hastings and Dakota railway,		872.5
Crossing of Twenty-ninth and One-half street,		872
Crossing of Lake street,		871
Crossing of Thirty-first street,		869
Crossing of Blaisdell avenue,		870
Crossing of Lindley avenue,		871
Crossing of Pleasant avenue,		876
Crossing of Grand avenue,		876
Crossing of Harriet avenue,		877
Crossing of Rogler avenue,		878
Crossing of Lyndale avenue,	3.11	877
Crossing of Aldrich avenue,		876.5
Crossing of Bryant avenue,		876
Crossing of Colfax avenue,		877
Crossing of Dupont avenue,		878
Crossing of Emerson avenue,		879
Crossing of Fremont avenue,		880.5
Crossing of Girard avenue,		881.5
Crossing of Hennepin avenue,	3.61	883
Crossing of Humboldt avenue,		881
Crossing of Irving avenue,		882
Crossing of Knox avenue,		883
Crossing of Thirty-second street,		885
Crossing of Thirty-third street,		883.5
Depot at lake Calhoun,	4.14	883.5
Depot at lake Harriet,		862
Crossing of the centre line of section 8,		891
Crossing of the centre line of section 7,	6.80	903
Crossing of Minnehaha creek, water 866; bottom 860,	7.44	871
Marsh, water 867; bottom, 853,	7.54	871
Crossing centre line, section 19 (Mendelssohn), natural surface, 933,	9.44	920
Crossing of Hastings and Dakota railway,	10.14	898
Crossing of Minneapolis and St. Louis railway,	10.54	901
Marsh, N. W. ¼ section 25, water 885,	10.74	889
Divide, N. E. ¼ section 27,	12.14	953
Depression, S. W. ¼ section 27, near Glen lake,	13.14	906
Marsh, near centre section 33; water 918,	13.64	924
Divide,	14.64	945
Purgatory creek, S. W. ¼ section 29, water 860.5; bottom 858,	15.44	897
Divide, natural surface 994,	17.44	975
Marsh, part of Christmas lake, surface 915,	18.44	920
Crossing of Minneapolis & St. Louis railway at Excelsior,	18.50	921.8
Junction of Hutchinson extension, at Excelsior, with the old motor line.	18.79	922
Excelsior depot,	18.97	928
Excelsior depot of the Minneapolis and St. Louis, same level as this road,	19.54	931
Crossing of line, sections 32 and 33.	21.79	965
Crossing of Carver county line.	22	968

	Miles from Bridge Square.	Feet above the sea.
Depression near lake Minnewashta,	24	933
Crossing Minneapolis and St. Louis railway, end of Schutz lake,	24.09	959.5
Centennial lake, water 930,	25.01	934.24
Summit N. E. corner of section 4,	27.22	977
Outlet of Parley lake, north side section 5, water 910,	28.79	928
Summit,	30.09	959
Clearwater lake, Coney Island station, water 946,	31.05	953
S. W. ¼ section 2,	32.15	957
Crossing of line, sections 3 and 4,	35.81	961
Crossing of Crane creek, centre of section 2, bottom 913,	37.85	938
Crossing of line, sections 4 and 5, T. 116, R. 116,	40.19	971
Crossing of Crane creek, W. ½ section 6, bottom 934,	42.24	943
Otter creek, E ½ section 1, bottom 938,	42.85	947
Lester Prairie station,	43.95	960
E. ½ section 4, T. 116, R. 27 (Lutheran church),	45.60	1007
Outlet of Mud lake,	50.26	1024
Summit, E. ½ section 4, T. 116, R. 28,	51.47	1040
Crossing of Bear creek, E. ½ section 6, T. 116, R. 28, bottom 1009,	53.36	1028
Summit, W. ½ section 2, T. 116, R. 29,	56.15	1053
Summit, W. ½ section 4, natural surface 1062, highest point on the line,	58.15	1053
Crossing of Crow river, bottom 1006,	59.75	1027
Hutchinson station, corner of Washington and Adams streets,	60.05	1023

Miscellaneous elevations in Hennepin county.

	Feet above the sea.
Minneapolis city datum, according to the city engineer,	712
Cedar lake, according to the city engineer of Minneapolis,	860
Lake of the Isles, according to the city engineer of Minneapolis,	856
Lake Calhoun, according to the city engineer of Minneapolis,	855
Lake Harriet, according to the city engineer of Minneapolis,	848
Union depot (according to the St. Paul and Northern Pacific railway),	813
Stone-arch bridge (grade of the St. Paul, Minneapolis and Manitoba railway),	807
Stone-arch bridge, race-way from the Pillsbury (A) mill,	743
Stone-arch bridge, main river beneath,	747
Stone-arch bridge, average water at its west end (head of the falls),	800
Stone-arch bridge, high water at its west end,	806
The limestone ledge, fifteen feet thick, under the west end of the stone-arch bridge, is between 769 and 784.	
Depot of the Chicago, Milwaukee and St. Paul railway (Washington avenue),	825
Crossing of Hennepin avenue and Thirty-sixth street,	882
Mouth of the deep well sunk at the Lakewood cemetery, about	900
Ordinary low water of the Mississippi river at Dayton,	843
Ordinary low water of the Mississippi river at Champlin,	829
Ordinary low water of the Mississippi river at the mouth of Rice creek,	804
Ordinary low water of the Mississippi river above the falls of St. Anthony,	800
Ordinary low water of the Mississippi river under the stone-arch bridge,	747
Ordinary low water of the Mississippi river half a mile below the falls,	720
Ordinary low water of the Mississippi river at the mouth of the Minnesota (high water, 710),	688
Ordinary low water of the Minnesota river at Bloomington ferry,	689
Ordinary low water of the Minnesota river at the foot of the Little rapids (near Carver),	690
Lake Minnetonka,	928
Crow river at Delano (in Wright county), about	912
Crow river, section 9, Hassan,	859
Crow river, Dayton,	843

Average elevation of Hennepin county. The following estimates have been made for the average elevation of the various towns of Hennepin county, and of the whole county. In the result obtained for the whole county the various fractional towns are allowed the values that are in proportion to the areas they contain: Hassan, 950 feet; Dayton, 935; Champlin, 875; Greenwood, 950; Corcoran, 975; Maple Grove, 960; Brooklyn, 840; Independence, 960; Medina, 940; Plymouth, 945; Crystal Lake, 880; Minnetrista, 970; Excelsior, 950; Minnetonka, 930; Minneapolis (including the city on the west side of the river), 880; St. Anthony (including Minneapolis on the east side of the river), 840; Eden Prairie, 900; Richfield (including Fort Snelling), 900; Bloomington, 875. The average elevation of the county thus would be about 922 feet above the sea.

Soil and timber. In general two different types of soil are found in the county, dependent on the nature of the respective subsoils. By far the larger portion of the county has a soil dependent on the gray till, or "blue clay," as subsoil. Perhaps the southeastern one-fourth of the county, not including the area along the Mississippi and Minnesota rivers that is approximately level and has a subsoil of gravel and sand, is dependent on the red till as subsoil. There is a wide belt along the Mississippi, widening from Dayton southward to the mouth of the Minnesota, and extending up the Minnesota valley, which is dependent on a subsoil of gravel and sand. This has a very uniform character. This gravel and sand is sometimes over a hundred feet thick, but it is generally less than twenty. It becomes thinner and thinner at points further from the river, until it completely gives place at the surface to the till deposit which underlies it.

The areas of these various general divisions cannot be minutely defined, for two reasons; first, the tills sometimes change gradually, and almost imperceptibly into each other, and show small isolated areas of one or the other separated from the general area, along the common boundary. The gravelly subsoils also sometimes ascend the tributary valley, and spread over considerable flat areas that are embraced in the till tracts, or connect with the gravelly and hilly morainic regions in the central portions of the county; second, there is another deposit, which actually forms the soil in much of the county, and particularly in all the lower levels, the origin of which is less evident and which screens the subsoils from observation. This covers all the flat areas, and in the western part of the county it also constitutes the surface when the general contour is much broken. It sometimes reaches the thickness of ten or even twenty feet. It is a loam, which varies from very clayey to very sandy, and which seems to partake locally of the nature of the underlying subsoil.

In general, however, with exception of the gravelly plains, the red till subsoil may be described as occupying the northeastern part of Eden prairie, the whole of Bloomington, the whole of Richfield, the southeastern half of Minnetonka, all of Minneapolis except the rolling country extending from the lake of the Isles northeastwardly to and beyond Bassett's creek, and small areas in the southeastern part of Crystal Lake. Even within this described tract there are small patches of gray till and of rolling gray gravel and sand overlying the red till, and sometimes alternations of the two, and intimate mixtures, seen in some of the exposed sections along the bluffs of Bassett's creek.

The forest. Three distinctions, both in respect of the geographic distribution of the forest, and the sorts of trees found in each, will be noticed by any observer who travels over the county: 1st. *The areas of flat land accompanying the great valleys*, particularly the Mississippi and Minnesota valleys. These plains were originally quite destitute of trees over large tracts, and nowhere were they heavily timbered. The bottom-lands, however, which are subject to overflow by the rivers, were covered generally quite heavily with species of elm, soft maple, bass and cottonwood. The only timber found on these plains was small, confined to sheltered nooks about some of the lakes, or to the sandy knolls where fires found no grassy vegetation to enable them to reach the trees. The species were black and bur oak, and trembling aspen. 2nd. *The areas of the red till, or red-clay subsoil.* The trees throughout this tract, which is quite hilly for the greater part, reach a greater size and a more numerous list of species than on the plains, but still would be classed as sparse and small. Throughout this area of sparse and small timber there are occasional large bur oaks on the uplands, and also occasionally gigantic black oaks with charred trunks, sometimes standing in clusters, having no other company than an undergrowth of oak bushes, like lingering sentinels still holding the ground against the inroads of the fires that for years have swept over and subdued the country further south and east, long after their companions had fallen and the main body of the forest had retreated several miles further west. There are also, in the bottom-land along some of the ravines, occasional trees of elm and bass. 3rd. *The area of the gray till.* This includes the most of the county, and on it the trees reach their greatest development both as to size, frequency and variety. Here are found all the species that are known to characterize the "Big Woods" of the state, such as elm, sugar maple, bass, butternut, aspen, ironwood, oak, ash, box elder, black cherry, etc. This forest supplies fuel to Minneapolis, and material for some of her manufactures.

The following species of trees and shrubs are known to grow in the county. The trees are named in the estimated order of frequency.

Ulmus Americana, *L.* (*Pl. Clayt.*) *Willd.* American elm.
Tilia Americana, *L.* Bass. Linden.
Acer saccharinum, *Wang.* Sugar maple.
Quercus coccinea, *Wang.* var. tinctoria, *Gray.* Black oak.
Juglans cinerea, *L.* Butternut.
Acer dasycarpum, Ehr. Silver maple.
Quercus macrocarpa, *Michx.* Bur oak.
Acer rubrum, *L.* Soft maple.
Populus tremuloides, *Michx.* Aspen.
Fraxinus Americana, *L.* White ash.
Quercus rubra, *L.* Red oak.
Ulmus fulva, *Michx.* Red elm.
Ostrya Virginica, *Willd.* Ironwood.
Fraxinus sambucifolia, *Lam.* Black ash.
Prunus Americana, *Marsh.* Wild plum.
Carya amara, *Nutt.* Bitternut.
Amelanchier canadensis, *Torr and Gray.* Juneberry.
Pyrus coronaria, *L.* Crab apple.
Larix Americana, *Michx.* Tamarack.
Negundo aceroides, *Mœnch.* Box elder.
Populus monilifera, *Ait.* Cottonwood.
Populus grandidentata, *Michx.* Great-toothed poplar.
Prunus serotina, *Ehr.* Black cherry.
Carpinus Americana, *Michx.* Water beech.
Salix nigra, *Marshall.* Willow.
Celtis occidentalis, *L.* Hackberry.
Betula papyracea, *Ait.* Paper or canoe birch.
Quercus Alba, *L.* White oak.
Juniperus Virginiana, *L.* Red cedar.
Pinus Strobus, *L.* White pine.

[The white pine grows sparsely on the banks of Minnehaha creek, near its mouth; also at the Inglewood and Glenwood springs in the valley of Bassett's creek, and at Dayton on the Mississippi.]

Populus balsamifera, *L.* var. candicans, *Ait.* Balm of Gilead.

[On the east side of the Mississippi below the University.]

In cultivation the following sometimes can be seen:
Picea nigra, *Link.* Black spruce.
Abies balsamea, *Marshall.* Balsam fir.
Thuya occidentalis, *L.* American arborvitæ.
Pinus Banksiana, *Lambert.* Jack pine.
Populus dilatata, *Ait.* Lombardy poplar.
Populus alba, *L.* Silver-leaf poplar.
Betula alba, var. populifolia, *Spach.* American White birch.
Costanea vesca, *L.* Chestnut.*

* At Wayzata the following species were noted in August, 1880: Black oak, bur oak, white elm, basswood, red elm, ironwood, cottonwood, aspen, black ash, choke cherry, Juneberry, white birch, white ash, soft maple, box elder, bitternut, tamarack, saghorn sumac, red cedar, false indigo, prickly ash, hackberry and wolfberry.

Shrubs.

Ampelopsis quinquefolia, *Michx.* Virginia creeper.
Celastrus scandens, *L.* Bittersweet.
Vitis cordifolia, *Michx.* Frost grape.
Corylus Americana, *Walt.* Hazel.
Rhus glabra, *L.* Smooth sumac.
Prunus Pennsylvanica, *L.* Wild red cherry.
Symphoricarpus occidentalis, *R. Br.* Wolfberry.
Rubus occidentalis, *L.* Black-cap raspberry.
Rubus villosus, *Ait.* High blackberry.
Rubus strigosus, *Michx.* Red raspberry.
Prunus Virginiana, *L.* Choke cherry.
Cratægus coccinea. Thorn.
Rosa blanda, *Ait.* Rose.
Xanthoxylum Americanum, *Mill.* Prickly ash.
Rhus typhina, *L.* Staghorn sumac.
Cornus circinata, *L'Her.* Round-leaved cornel.
Sambucus Canadensis, *L.* Common elder.
Viburnum Opulus, *L.* High-bush cranberry.
Ribes floridum, *L.* Black currant.
Cornus alternifolia, *L.* Alternate-leaved cornel.
Cornus paniculata, *L'Her.*
Cornus stolonifera, *Michx.* Red osier dogwood.
Alnus incana, *Willd.* Speckled alder.
Viburnum Lentago, *L.* Sheep berry.
Sambucus pudens, *Michx.* Elder.
Lonicera parviflora, *Lam.* Honeysuckle.
Lonicera ciliata, *Muhl.* Honeysuckle.
Lonicera flava. Sims. Yellow honeysuckle.
Cornus sericea, *L.* Kinnikinnick.
Cornus Canadensis, *L.* Dwarf cornel.
Ribes Cynosbati, *L.* Prickly wild gooseberry.
Ribes rotundifolium, *Michx.* Smooth wild gooseberry.
Spiræa tomentosa, *L.* Hardhack.
Spiræa salicifolia, *L.* Meadow-sweet.

THE GEOLOGICAL STRUCTURE.

The geology of the indurated rocks of the county requires but a brief chapter. The only outcrops known in the county belong either to the Cretaceous or the Palæozoic. Of the latter the Mississippi and its immediate banks afford the only exposures. These are either of the Trenton limestone or the St. Peter sandstone. The Cretaceous is found in the banks of Crow river in a few scattered and unimportant cuts made by that stream. The respective areas of these formations, so far as they can be ascertained or estimated, are shown on the accompanying colored map of the county. The drift deposits effectually screen the underlying rocks throughout the most of the county, and the color that represents the drift, is, therefore, the prevailing one on this map. But the drift deposits, in connection with the relations they bear to the gorge cut by the recession of the falls of St. Anthony, are an important and fruitful theme in any account which may be attempted of the geology of Hennepin county. Some deep wells that have been bored at Minneapolis give information concerning the strata below the St. Peter sandstone, underlying the eastern part of the county, and they are given first.

Deep wells at Minneapolis.

Following are the records of several wells that penetrated the strata underlying the St. Peter sandstone at Minneapolis.

The deep well drilled at East Minneapolis in 1874–1875.

The following record of this well, which begins at about 850 feet above the sea, was furnished by Col. J. B. Clough, city engineer, in whose charge the work was placed by the city council when money was appropriated by it to aid the enterprise. This occurred at the depth of about 1,000 feet.* This well is situated near the bluff of the river a little above the falls of St. Anthony. It is now covered by the building of the Minneapolis exposition. Water stands at about fifteen feet below the surface.

		Thickness.	To what depth.
1.	Sand,	42 feet.	42 feet.
2.	Blue limestone,	28 feet.	70 feet.
3.	White sandstone,	164 feet.	234 feet.
4.	Red limestone,	102 feet.	336 feet.
5.	Gray limestone,	16 feet.	352 feet.
6.	White sandstone,	116 feet.	468 feet.
7.	Blue shale,	128 feet.	596 feet.
8.	White sandstone,	82 feet.	678 feet.
9.	Blue shale,	170 feet.	848 feet.
10.	Sandy limestone,	9 feet.	857 feet.
11.	White sandstone,	130 feet.	987 feet.
12.	Sandy marl,	8 feet.	995 feet.
13.	White sandstone,	79 feet.	1074 feet.
14.	Red marl,	57 feet.	1131 feet.
15.	Red sandstone and red marl,	290 feet.	1421 feet.
	Total depth,		1421 feet.

Notes. The sand of No. 1 is at first the sandy loess of the Mississippi valley, but is underlain by a true drift sand and gravel, the latter making about 25 feet of the thickness here given. Under the drift-gravel is a varying thickness of red till which seems not to have been encountered in this well, although it is abundantly seen overlying the rock (No. 2) less than a block distant along Central avenue, and is found generally throughout the east division of the city. Sometimes, however, a blue till is found instead of a red one, and sometimes both, the blue overlying the red.

The limestone of No. 2, with some beds of green shale, embraces the bottom beds of the Trenton formation, and, in conjunction with the underlying sandstone, is the cause of the falls of St. Anthony.

No. 3 is known as the St. Peter sandstone, and here it gives, with one exception, a greater meas-

* Compare the bulletin of the Minnesota academy of natural sciences for 1875, p. 187.

ured thickness than is known at any other place in the state. It may include, at the bottom, a shaly representative of the Shakopee limestone.

Nos. 4 *and* 5 cover the horizons of the Shakopee limestone, the Richmond sandstone and the Lower Magnesian limestone, the whole making a thickness of 118 feet. As an individual member of the Cambrian, the Richmond sandstone does not here appear. It must have escaped observation, being thin, or may have been wholly wanting. It is also quite possible that the Shakopee, which was very shaly in the Mendota deep well, amounting to a thickness of thirty feet, was here considered as a part of the St. Peter sandstone, thus augmenting that formation, and that the rock represented by Nos. 4 and 5 is actually referable entirely to the Lower Magnesian. This is also sustained by the record of the Lakewood cemetery well where the thickness of the dolomitic rock at this horizon does not exceed eighty-five feet.

No. 6 is therefore the Jordan sandstone.

No. 7 represents the St. Lawrence limestone, though here its calcareous ingredients were so reduced as to cause it to be designated a shale. Everywhere the St. Lawrence limestone is associated with a great thickness of shale.

No. 8 is about on the horizon of the Dresbach sandrock.

Nos. 9 *and* 10 have no distinguishing appellations though they are constant strata (particularly No. 9) in the records of deep wells in the eastern part of the state.

Nos. 11, 12 *and* 13 are probably the Hinckley sandstone, seen in the gorge of Kettle river.*

Nos. 14 *and* 15 belong to the Cupriferous formation of lake Superior, and seem also to be the equivalents of the red shales and sandstones that appear in the southwestern part of the state containing the well-known red pipestone or catlinite.†

The deep well at the Washburn "C" mill.

The deep well at the Washburn "C" mill begins at about 825 feet above the sea; situated near the river on the west side opposite the falls of St. Anthony.

		Thickness.	To what depth.
1.	Peaty black soil,	2 feet.	2 feet.
2.	Drift sand and stones,	8 feet.	10 feet.
3.	Limerock, gray and blue,	24 feet.	34 feet.
4.	Blue clay (shale),	2 feet.	36 feet.
5.	White sandrock,	44 feet.	80 feet.
6.	Yellow sandrock,	7 feet.	87 feet.
7.	White sandrock,	41 feet.	128 feet.
8.	Yellow sandrock,	3 feet.	131 feet.
9.	Fine, white sandrock,	22 feet.	153 feet.
10.	Yellow sandrock,	5 feet.	158 feet.
11.	White sandrock,	2 feet.	160 feet.
12.	Pipestone clay, reddish brown,	2 feet.	162 feet.
13.	Coarse white sandrock, water rising from this to the surface,	21 feet.	183 feet.
14.	Coarse, gray sandrock,	17 feet.	200 feet.
15.	Hard, gray sandrock,	4 feet.	204 feet.
16.	Red rock (grit), penetrated only,	1 foot.	205 feet.
	Total depth,		205 feet.

Notes. The St. Peter sandstone includes the members from No. 5 to No. 15, both inclusive, aggregating 168 feet, or four feet more than in the well on the east side of the river at Minneapolis. The transition from the hard gray sandrock of No. 15 to the red grit-rock of No. 16 seems to be so abrupt that there is no probability of the existence, here, of any shaly Shakopee as at Mendota. Therefore, as in the last well, the next formation (entered but one foot) probably represents the commencement of the dolo-

* Compare the eleventh annual report, p. 125.

† Compare the thirteenth annual report, p. 65.

mitic beds that are in other places divisible into three separate alternating beds — the Shakopee limestone, the Richmond sandstone, and the Lower Magnesian limestone.*

The pipestone clay, No. 12, is undistinguishable from the brownish-red shale seen in the brown sandstones at Fond du Lac, near Duluth. It is somewhat schistose in one of the fragments, and also has spots of green similar to the green spots seen in the same clay at Fond du Lac. In its schistose character it resembles some of the schistose soapy clays seen in the formation at Baraboo, Wisconsin, and at Sioux Falls, Dakota. It generally is a shale, and has an angular fracture. In the midst of some of the fragments can be seen a little grit cemented by the same substance that cements the red rock of No. 16. This reddish-brown clay was not noted in the record of the East Minneapolis well, but it was by that of the West hotel well. It confines a stratum of water under hydrostatic pressure, and hence when punctured the water rises nearly or quite to the surface of the ground. This indicates that the stratum of clay is of considerable extent laterally, and was penetrated, but not noticed, in the well at East Minneapolis.

All the sands underlying the blue clay below the Trenton limestone are essentially the same in character, being composed of rounded grains of pure quartz. These grains differ in size, the largest being about as large as a mustard seed and the smallest too minute to be distinguished by the unaided eye. They differ in color somewhat, passing from a pure limpid glass to snowy white, and to a buff color, and to a smoky gray. These colors are not due to the cement in which the grains are inclosed, but to an actual difference in the quartz itself. This difference in color implies some change in the source of the material, and suggests the inquiry whether that change were not in the waters of the ocean rather than on the land. On the supposition that this pure quartz was the result of chemical precipitation, these different colors in the same formation are easily accounted for by such changes as may have occurred in the ocean by shifting currents, allowing the mingling of certain other substances in solution with the precipitated silica, so as to stain it as it is. On the supposition that this sand is derived from the pre-existing land as a detrital sediment, it is very difficult to understand how such a source of pure silica, almost absolutely free from other sand and impurities, could be obtained and disseminated so widely as this sand is known to extend, and to change its inherent color from time to time.

No. 16, which is the red limestone, so-called, of the East Minneapolis well, was examined carefully when the West hotel well was drilled, the record of which is given next below. So far as the drillings of the Washburn "C" mill well indicate, it is a firm red grit, but has a cement that effervesces feebly in hydrochloric acid, and finally disintegrates to rounded quartz grains. It might be styled a dolomitic quartzyte, though its cement is also ferruginous.† At greater depth it seems to change to dolomitic rock.

The West hotel well.

This well begins at about 835 feet above the sea-level. It is about half a mile from the river on the west side. The water stands at twenty-four feet below the surface. Pumping at the rate of 300 gallons per minute lowers the water, according to Mr. W. E. Swan who drilled the well, about three feet in the pipe. The water is used at the West hotel.‡ The first water was encountered in No. 8, below a bed of four feet of red shale, the same that was met, with the same result, in the Washburn "C" mill well.

			Thickness.	To what depth.
1.	Mus. Reg. No. 6072.	Drift, sand and gravel,	18 feet.	18 feet.
2.	Mus. Reg. No. 6073.	Limerock (Trenton),	10 feet.	28 feet.
3.	Mus. Reg. No. 6074.	Green shales (Trenton),	10 feet.	38 feet.
4.	Mus. Reg. No. 6075.	White sandrock,	91 feet.	129 feet.
5.	Mus. Reg. No. 6076.	Yellow sandrock,	30 feet.	159 feet.

* See the tenth annual report, p. 212.

† In the first account given of this well (tenth annual report), the cement was regarded as felsitic, but it is not likely that there is any other than free silica embraced in the cement.

‡ See the fourteenth report, p. 11.

		Thickness.	To what depth.
6.	Mus. Reg. No. 6077. Yellow sandrock,	5 feet.	164 feet.
7.	Red shale.	4 feet.	168 feet.
8.	Mus. Reg. No. 6078. White sandrock (first water),	10 feet.	178 feet.
9.	Mus. Reg. No. 6079. Yellow sandrock, -	18 feet.	196 feet.
10.	Mus. Reg. No. 6080. Gray sandrock,	6 feet.	202 feet.
11.	Mus. Reg. No. 6081. Red quartzyte, with calcareous cement effervescing feebly,	32 feet.	234 feet.
12.	Mus. Reg. No. 6082. Fine (crypto-crystalline) limestone, hard, drab, siliceous,	40 feet.	274 feet.
13.	Mus. Reg. No. 6083. Red limestone, siliceous, hard, fine, verging to the drab limestone of No. 12,	10 feet.	284 feet.
14.	Limestone with white sand intermixed, similar to No. 12, but rather yellowish-pink than drab in color,	15 feet.	299 feet.
15.	Brown-red, hard rock, a calcareous quartzyte, some of it being a fine siliceous limestone,	6 feet.	305 feet.
16.	Fine, light-pinkish limestone, with numerous white quartz grains intermixed. The drillings are nearly half sand, but Mr. Swan thinks there is no sand in this rock (No. 16) but that the sand works in from above; which is probably true,	30 feet.	335 feet.
17.	White sand (second water),	5 feet.	342 feet.
18.	Fine pinkish sand, very hard,	1 foot.	343 feet.
19.	Rounded, coarse, white sand (water increased to 20),	90 feet.	433 feet.
20.	Calcareous shale, (?)	45 feet.	478 feet.
21.	Green shale,	104 feet.	580 feet.
22.	Hard, sub-crystalline shale, greenish, slaty,	12 feet.	592 feet.
23.	White sand stone (third water). Dresbach sandstone, (?)	30 feet.	622 feet.
	Total depth,	622 feet.	622 feet.

Notes. Of the above record the St. Peter sandstone extends to, and includes, No. 10. and shows variations in color similar to those noted in the record of the well of the Washburn "C" mill. Nos. 11–16 comprise a reddish, quartzitic and dolomitic rock, aggregating 133 feet in thickness, which is on the same horizon as the "red limestone" and the "gray limestone" of the East Minneapolis well. The Jordan sandstone is represented by Nos. 17, 18 and 19, ninety-six feet thick. The St. Lawrence limestone is included in the shaly member represented by Nos. 20, 21 and 22; and No. 23 is probably the upper part of the Dresbach sandstone.*

The Lakewood cemetery well.

This well was drilled with the hope of getting artesian water to supply the cemetery. The work was done by Mr. F. M. Gray. It begins about 75 feet above the depot of the Chicago, Milwaukee and St. Paul railway, at Minneapolis, and hence about 900 feet above the sea, and about fifty feet above the tamarack marsh which extends between lakes Calhoun and Harriet. It is south of lake Calhoun, near the margin of this marsh, about four miles and a half from the Mississippi.*

		Thickness.	To what depth.
1.	Gravel and sand; mainly referable to the blue till as its source. It is suitable for road-making; the upper portion of this, not noticed by Mr. Gray, cousists of yellow loam, such as covers the most of the country, making the soil, having a thickness of 1-4 feet (Mus. Reg. No. 5723), -	135 feet.	135 feet.

*Samples of the drillings of this well are preserved in the general museum.

	Thickness.	To what depth.
2. Yellowish, ochery, or rusted clay in which the stones, and all boulders, one of which was broken and brought up in fragments, have a ferruginous coating or weathering,	3 feet.	138 feet.
[This seems to have been the bottom of the old preglacial (rather interglacial) river gorge. It is evinced by this weathered material. A boulder of syenitic gneiss as large as a man's fist, which was said to have been brought up in the pump, was exhibited by the men at work. It was weathered and looked so much like a surface pebble, such as can be found anywhere now on the top of the ground, that at first this statement was disbelieved. But when the superintendent showed a piece of hard gray granite, evidently freshly fractured by the drill, having a red weathered exterior, I was inclined to believe that the pebbles of gneiss also may have come from this depth.]		
3. Blue till, -	74 feet.	212 feet.
4. Gravel and sand and blue till. This was changeable, and seemed to be as if interstratified, but of course that could not be stated on the basis simply of the pumpings,	36 feet.	248 feet.
5. Boulders of Trenton limestone, and of granite, with some sand all more or less involved with some blue till. The rock was struck next below this, and at a depth of 264 feet beneath the surface. This depth seems to demonstrate the existence of some great excavation in the strata, probably the old gorge of the Mississippi river,*	8 feet.	256 feet.
6. Quartzose sandstone, in friable strata or massive, composed of rounded grains of pure quartz (Mus. Reg. No. 5724),	20 feet.	276 feet.
7. The same (Mus. Reg. No. 5725), -	20 feet.	296 feet.
8. The same (Mus. Reg. No. 5727),	22 feet.	318 feet.
9. At the depth of 318 feet about one-half of the washed drillings are found to consist of dolomitic rock, and the rest of the same white sand. Some of the coarser fragments show that this dolomite is compact, fine-grained, of a yellowish-gray color, approaching, in both respects, some of the strata of the Cambrian. Occasional fragments of crystalline rock, found in the drillings here, and before, evidently are derived from the drift below the point at which the pipe stands on the boulders, etc., of No. 5 (Mus. Reg. No. 5728),	4 feet.	320 feet.
10. At 325 feet the pumpings consist almost entirely again of white sand. Hence the dolomitic layers seem to have been not greater than ten feet in thickness (Mus. Reg. No. 5730),	5 feet.	325 feet.
10½. At this point some pebble or other obstruction in the drill-hole caught the drill and caused the breaking of one of the wooden poles, and a delay, the drill being lodged and wedged fast. When the drill was started again and the pumpings were preserved, the samples exhibited were said to have come from the depth of 360–403 feet, and nothing was said of the interval between the last preserved record (325 feet) and 360 feet. Hence there is no certainty whether it contained drillings like those at 325 feet or at 360 feet,	35 feet.	360 feet.
11. Slightly red, fine-grained, dolomitic rock, of homogeneous characters (Mus. Reg. No. 5731), - - -	43 feet,	403 feet,

* Fifth annual report, page 177.

		Thickness.	To what depth.
12.	About one-half of the drillings are like the last, and the rest are of rounded, white, translucent, quartz-grains like the next. It is probable that the mixture is occasioned by the infrequency of the pumping, and not by an original mixture in the rock. The transition from dolomite to sandrock took place in this interval (Mus. Reg. No. 5732), -	13 feet.	416 feet.
13.	Translucent, rounded grains of quartz, almost nothing else (Mus. Reg. No. 5733),	8 feet.	424 feet.
14.	The same as the last. At the time of this visit the workmen exhibited some fragments consisting of white chert coated with fine rhombohedrons of dolomite of the same reddish color as the rock at No. 11, with a few scattered cubes of pyrite, but they could not assign any definite horizon to them, saying they picked them out of the pumpings. They are probably from the reddish dolomite, but may be from the top of the sandrock when the passage from one to the other is apt to alternate from sandrock to dolomite in thin beds accompanied by chert (Mus. Reg. Nos. 5734-5),	10 feet.	434 feet.
15.	White quartz sand, rounded (Mus. Reg. No. 5736),	47 feet.	481 feet.
16.	White quartz sand, with traces of light green shale, and occasional small, aggregated, clustered, cubes of pyrite, the clusters being about the size of mustard seeds (Mus. Reg. No. 5737),	23 feet.	504 feet.
17.	White quartz sand, rounded, with some green shale. In mass this does not appear so clearly white as the last two, but a dirty white, apparently due to some soft, colored material ground up by the drill, which, on getting dry, cements the sand grains into fragile lumps (Mus. Reg. No. 5738),	54 feet.	558 feet.
18.	White sand and green sand, the latter mainly ground to a fine powder, so as to stain the whole and make a greenish, fragile, loose mass, when dry. Some of the green sand is like the distinct green sand lumps seen in the St. Croix, at Red Wing (Mus. Reg. No. 5739),	49 feet.	607 feet.
18½.	[The interval unrepresented by drillings, from 607 feet to 694 feet, probably was made up of the same as the last],	87 feet.	694 feet.
19.	White sand (Mus. Reg. No. 5740), -	69 feet.	763 feet.
20.	Mainly white sand, but having a mixture of other grains that are not silica, and of a heavy cementing substance that, when dry, seems to be a powdered rock of some sort, of a light buff and pinkish color. The mass, however, does not fervesce. Some scattered grains are green and soft, and may be the source of the coloring cement (Mus. Reg. No. 5741).	17 feet.	780 feet.
21.	Green clay or shale; non-effervescing, very fine-grained (Mus. Reg. No. 5742), -	155 feet.	935 feet.
22.	White sand, with a faint yellowish tint (Mus. Reg. No. 5743),	60 feet.	1005 feet.
23.	Siliceous sand, with a faint pinkish tint, rather fine (Mus. Reg. No. 5744),	5 feet.	1010 feet.
24.	Siliceous sand, with a deeper pinkish tint, rather coarse grain, some of the grains being amethystine, and others of a light yellow color (Mus. Reg. No. 5745),	50 feet.	1060 feet.
25.	Siliceous sand like the last, but of a lighter color (Mus. Reg. No. 5746), -	45 feet.	1105 feet.
26.	The same, but cemented, when dry, with ground-up, reddish shale, probably derived from some beds introductory to the next (Mus. Reg. No. 5747), - - -	18 feet.	1123 feet.

	Thickness.	To what depth.
27. Compact, red clay, or shale, like that seen at Fond du Lac, below the red sandrock, and interstratified with it (Mus. Reg. No. 5748),	44 feet.	1167 feet.

[At some places between 1123 and 1167 feet, several pieces of red shale, mottled with light green, were brought up by the pump. Some of these are two inches across. They are fine-grained, gritless and sparkle with fine flakes of talc or mica. The green portions of this shale are finer grained than the red, and also are harder. The red has a powder that is reddish-umber in color, and the green parts have a powder nearly white, or at least greenish-white. Within the green can be seen, under the loop, scattered, distinct grains, of much darker green, nearly black, which are about as hard as talc, and crush easily under pressure, with a greenish powder. The greenish shale seems to be subcrystalline. It occupies patches that are broad but thin, and constitutes but a small part of the whole; but it is intimately blended with the red in structure. According to Mr. Gray, this reddish-brown shale gradually became harder, and at 1235 feet it was a hard rock, and continued so to at least the depth of 1286 feet, where the drill was at work when this information was obtained.

At 1235 feet a somewhat harder stratum was reached. The drillings have a reddish color, but show angular fragments of gray or greenish slaty rock, soft, gritless, glittering with fine flecks and resembling Nos. 450 and 452 of the geological survey series (blue), but less hard. These fragments evidently show the nature of the rock at this depth, the red color of the drillings being caused by intermingling with material from the overlying beds, the well at this depth not being piped. Some of the fragments of gray or light green shale are an inch across. The sand grains, and all the reddish coloration, are undoubtedly from the higher strata. The gray-green shale is fragmental, not crystalline, except as it may contain grains from the crystalline rocks, glitters with light-colored scales of mica, macerated by water and friction, and also holds rounded grains of a green substance, which outwardly is nearly black but within is much lighter, and which mashes easily; evidently the same substance as mentioned already.]

28. Reddish-brown schist, hardness about four and one-half or five with a gray streak or powder, glistening with reflecting, minute points of some mineral which it is impossible to name, but which may be mica scales. This has the general outward aspect of an impure hematite, but its powder and its weight show it is not an iron ore of any kind. On washing a considerable qnantity of the drillings from this interval (really labeled from 1260–1380 feet), the residue consists of grains of a great variety of rocks, demonstrating that great care must be taken in drawing inferences from the appearances of the drillings furnished by the usual well driller, and that the drillings from the npper portions of the well are constantly mixed with those derived from below, in snch abundance often as to screen entirely the true character of the lowest strata from the notice of the geologist. The grains in this instance consist of the following kinds: (1) Conspicuously, white, limpid sand. (2) Brown schist, with a gray or light streak, making the greater part. (3) Soft greenish

	Thickness.	To what depth.
slate. (4) Red, soft shale with spots of green. (5) A few bits of an arkose-like sandstone, with a pea-green interior color. (6) A gray, hard, fine-grained schist, not foliated like (2), but having an angular fracture, as if massive, and (7), A single, large piece, of a dark, medium-grained, massive rock, like a dioryte. These last (6 and 7) evidently are from near the bottom of the drill, as they are the last to appear among the drillings. (Mus. Reg. No. 5751–54.)	33 feet.	1400 feet.

Notes. The foregoing record may be summarized as follows. Numbers 1 to 5 represent the drift, two hundred and fifty-six feet in thickness; numbers 6, 7 and 8 are embraced in the lower portion of the St. Peter sandstone, the upper part being excavated and the valley filled by drift, sixty-two feet; numbers 9 and 10 are at the horizon of the Shakopee limestone, and since they are succeeded downward by a white sandstone of unascertained thickness, though not exceeding thirty-five feet, they probably represent actually the true Shakopee limestone, with an ascertained thickness of ten feet; number $10\frac{1}{2}$ covers a bed of sandstone which would be the Richmond sandstone. Its thickness may not have exceeded ten feet, but in the absence of any record it may be assumed to have been thirty-five feet, thus filling the interval between the two points at which dolomitic rock is known. Numbers 11 and 12 represent the Lower Magnesian limestone, at least its lower portion, fifty-six feet. Numbers 13, 14, 15, 16 and 17 plainly belong to the Jordan sandstone, about a hundred and forty feet thick. Numbers 18 and $18\frac{1}{2}$ make the shaly and green sand stratum in which is contained the St. Lawrence limestone, here amounting to a hundred and thirty-six feet. Numbers 19 and 20 seem to represent the Dresbach sandrock, eighty-six feet in thickness. Number 21 is the equivalent of the shaly stratum which in the East Minneapolis well is given in the record at a thickness of one hundred and seventy feet, the same being here only a hundred and fifty four feet. Numbers 22 to 26, aggregating one hundred and seventy-eight feet, is the Hinckley sandrock, the same as numbers 11, 12 and 13 in the record of the East Minneapolis well. Numbers 27 and 28 are composed of a reddish-brown shale similar to that in which the drill stopped in the East Minneapolis well.

The above record ceases at 1400 feet, but the well was drilled subsequently to the depth of 2118 feet, without the preservation of drillings or reliable record. Samples said to have come from the bottom show a reddish-brown schistose or shaly rock, apparently still belonging to the same formation as the last above.

The St. Peter sandstone. Hennepin county contains the original and typical locality from which this sandstone was named.* It rises precipitously from the water level in both bluffs of the Mississippi from the falls of St. Anthony to the mouth of the Minnesota. It is not so constantly exposed in the bluffs below that point, but it exists as far as to near Red Rock, in Washington county. It is not visible in the banks of the Minnesota except for a short distance above Fort Snelling. Above the falls of St. Anthony it is exposed at a few points along the immediate river banks. On the east side it outcrops along main street, and is struck in digging wells at points further north and east. On the west side it is the surface rock where Bassett's creek enters the Mississippi, above the falls. That creek seems not to run at any point over the Trenton limestone. Its lower portion, for a mile or two

* Dr. D. D. Owen regarded it as a portion of the Lower Magnesian formation, *since it appears to have been produced by a repetition of sedimentary action similar to that which occurred just before the commencement of the Lower Magnesian.* Compare Owen's *report on the Chippewa land district;* 30th Congress, 1st sess. [Senate] Ex. Doc. No. 57, p. 28.

before it joins the Mississippi, seems to have been excavated in the St. Peter sandstone by some force more powerful than the creek itself, and at some time prior to the last glacial epoch. The St. Peter sandstone makes its last appearance in the banks of the Mississippi at the mouth of Shingle creek.

The physical characters of the St. Peter sandstone. The outward and also the chemical characters of this sandstone are remarkably constant and simple. It is white, "saccharoidal," friable, non-fossiliferous, (or almost so,) and consists almost entirely of pure quartz sand. It contains not enough lime to act as a cement, and hence can almost everywhere be excavated even with the fingers. On exposed surfaces, as along the bluffs of the Mississippi, where dripping water passes over it, the grains become more firmly cemented together by deposition of carbonate of lime and iron oxide, and its delicate whiteness is lost. Indeed, wherever water in the smallest quantity is allowed to trickle through it, a deposit of iron oxide is invariably seen, since rarely, if ever, is any surface water found entirely free from that impurity.

The St. Peter, operating in conjunction with the overlying Trenton limestone, is the immediate cause of a great many waterfalls. The falls of St. Anthony are caused by the passage of the Mississippi from the limestone on to the sandstone. The latter, worn away at the foot of the fall by the retroaction of the water, leaves the limestone projecting to fall down in heavy blocks as fast as it becomes too feeble to support further its own weight. This protecting cap of limestone extends but a few rods above the present brink of the falls; and had it not been that vigorous measures were taken a few years since for its protection, it is very probable that ere this the falls themselves would have disappeared, or changed to a foaming rapid, thus destroying, or greatly damaging, one of the most important water-powers of the world. The first alarm was occasioned by the effect of the water of the river in running through an artificial tunnel in the underlying St. Peter sandstone, and the collapsing of large areas of the limestone. The water was immediately excluded from the tunnel, the sandstone behind the waterfall was protected from the retro-action of the water, and a wall or dike of concrete or *beton* was constructed under the river in the sandrock, and below the limerock, crossing the Mississippi a short distance above the brink of the falls. This wall of concrete has a width of four feet and extends downward from the limerock to below the bottom of the river, below the falls. The chief object of this dike is to cut off all streams of water from running in the St. Peter and so perforating it and eroding it as to cause the downfall of the limerock. A number of such streams, some of considerable size, were found to be passing through the sandrock, having entered it from the river at points above the limit of the limerock. Being under considerable hydrostatic pressure their force of erosion on the sandrock was greater than ordinary surface streams of the same size The thickness of this sandstone at the falls of St. Anthony is given at 168 feet by the record of the deep well at the "C" Washburn mill. Other deep wells at Minneapolis find it 164 feet.

The Trenton shales and limestone. This formation is that which forms the brink of the falls of St. Anthony, and is seen in the river bluffs thence to Fort Snelling, and for a short distance up the valley of the Minnesota. It probably underlies the drift in the eastern part of Richfield, the most of Minneapolis, and Crystal Lake between Shingle creek and Bassett's creek. The drift is so thick, and its posé is so varied by other causes besides the nature of the underlying rock, that the extension of this limestone further west in Hennepin county cannot be said to be indicated, *pro* or *con*, by the surface contours. It is highly probable, however, that its area is confined to the above-mentioned limits. If it exceed these limits, such excess is most likely to be found in the western portions of Richfield and Bloomington and in the northeastern part of Eden Prairie. If it be found, hereafter, to extend into the northeastern part of Eden Prairie, it is very probable that it also will be found on the west side of the valley of Purgatory creek, and in the northeastern part of Carver county, along the south side of lake Minnetonka.

The composition of the Trenton, as it exists in Hennepin county, can be seen by reference to the sections that are given below. In general it may be said to have four main divisions, as follows, in descending order:

1. *Shales, with lenticular fossiliferous sheets of blue limestone; thickness, from* 0 *to* 30 *feet.*

2. *A somewhat magnesian and argillaceous limestone; thickness, from* 9 *to* 12 *feet.*

3. *Calcareous shale; thickness, from* 4 *to* 6 *feet.*

4. *Argillaceous, scarcely magnesian, limestone; thickness, about* 15 *feet.*

Of these parts the first is often spoken of as *green shales* in this report. They are sometimes called *soapstone,* but they do not contain the mineral constituents of soapstone, and should not have that name. Being soft and easily covered up they are generally hidden by the overlying drift at nearly all points along the river bluffs. The enclosed lenticular layers of fossiliferous limestone have their upper and lower surfaces sometimes literally covered with fossils in a fine state of preservation. There are also fossils distributed through the shales themselves, which, on the weathering of the shales, wash out in perfect preservation. Species of brachiopods and of bryozoa are most common in such situations. The same are cemented also on the slabs of limestone. These shales are exposed on the west side of the river in the vicinity of the quarry of Franklin Cook and others, about two miles below the falls of St. Anthony. In respect to palæontology this is the most interesting portion of the Trenton.

The sub-magnesian limestone, No. 2 above, is a well-known stratum. Its characters are not always distributed with uniformity through the whole thickness designated, but they are apt to fade out downward, allowing the extension of the characters of the next stratum below somewhat into this. This is a lighter colored rock than the limestone of No. 4, but it is not so much used for building purposes, indeed generally it is rejected.

The last stratum mentioned above is that which is used extensively as a building-stone at Minneapolis and St. Paul. The stone is rather too argillaceous to be a reliable building material. The shale is disseminated intimately 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 are more purely calcareous. The color of the whole is blue, which makes it have a deceptive appearance of strength and durability when placed in a structure. Below this stratum is a thin stratum of shale, exactly like that of the *green shales*, lying directly on the St. Peter sandstone. At Minneapolis this is about two feet thick, but it increases to about four feet at St. Paul.

Section of the Trenton below the University.

No. 1.—Impure limestone, crystalline, rough to the touch, hard, but splitting to thin lenticular chips under the weather. This is of a blue color within, but on exposed surfaces becomes a dirty buff. The grain is close, except for the cavities resulting from absorbed fossils. The fragments into which the stone weathers out are brittle and somewhat sonorous. It is very fossiliferous especially with *Strophomena minnesotensis.* It also has frequently associated with this, *Orthis tricenaria*, species of *Murchisonia*, *Leperditia*, *Cypricardites*, *Bucania*, and occasionally of *Asaphus.* Thickness not fully exposed; seen about - 8 feet.

No. 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, -	2 feet.
No. 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, - -	4 feet 8 inches.
No. 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 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, -	2 feet 4 inches.
No. 5.—Argillaceous limestone, the principal stratum of the Trenton. The fossil remains in this member are apt to be comminuted, so as to be wholly undistinguishable, yet sometimes large specimens 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 fossilliferous with forms of *Rhynchonella capax*, *Orthis*, and other brachiopods and incrusting corals. This is the principal and most constant member of the *Lower Trenton*. Thickness about -	15 feet.
No. 6.—Blue shale, parting conchoidally under the weather, lying on the St. Peter sandstone, -	2 feet.
Total,	34 feet.

The area of the Trenton in Hennepin county is divided into three parts by the gorge cut by the Mississippi,* and by that occupied by the lower part of the valley of Bassett's creek. There is also a deep re-entrant angle coming in from the north which perhaps divides that portion lying on the east of the Mississippi into two parts, in a manner similar to that on the west side where Bassett's creek, occupying an ancient gorge, separates the Trenton into two areas. But there is not sufficient evidence that this angle is produced far enough to actually divide the Trenton in Hennepin county, and the area in St. Anthony which was supposed formerly to be occupied by the St. Peter sandstone,† is shown, on the map of the county as underlain by the Trenton limestone, except so far as it is known that the angle extends.

On both sides of the river, a short distance above the falls, the strike of the Trenton limestone recedes from the river, passing inland, the space between the limerock and the actual channel being filled by drift materials, the lower portion of which is the gray laminated clay used for brick-making. The limestone bluff can be traced for some distance, running parallel with the present river gorge on both sides, the distance between them being about a mile at first, but widening to two miles. On the east side the edge of the rock swings

* Excepting the narrow neck two or three hundred feet wide which crosses the Mississippi causing the falls, and not including the islands in the river.

† See the map accompanying the fifth annual report.

round toward the east and southeast, forming the re-entrant angle above mentioned. It is supposed to return upon itself and run northward along the east side of Sandy lake, to the line of Anoka county where it is seen in outcrop. On the west side of the river it is very certain that from a short distance above the falls the edge of the limestone swings westward and southwestward, away from the river, redoubling on itself and connecting with the known limestone area in the southeast part of Richfield. If there be an area of this rock in the western part of Richfield it is probably an outlier, separated from that seen along the Mississippi above Fort Snelling by the ancient gorge of the river now occupied by lakes Calhoun and Harriet, lake of the Isles and Bassett's creek. Such outlier might be a large one, and, as already intimated, may run as far west as the valley of Purgatory creek, and, again recurring, may extend into Carver county south of lake Minnetonka. On the north side of the valley of Bassett's creek, between that creek and Shingle creek, is an isolated area of the Trenton limestone about three miles long north and south, and about two miles wide. While the condition of the Trenton above the falls indicates an old valley, dating back anterior to the last drift-epoch, that below the falls, extending to Fort Snelling as plainly shows a gorge that is post-glacial. The precipitous bluffs of the St. Peter sandstone, capped by the freshly broken Trenton limestone unscreened by drift deposits, rise directly from the present river channel, the space between the opposite bluffs being proportionate to the present size of the river, and plainly referable to the late recession of the falls of St. Anthony. Indeed the agent which is seen in operation to-day, breaking down the limerock and excavating the gorge, is at once assigned by the reflective observer to the existence of this gorge as far as the same bare, fresh, limestone bluffs extend down the valley. These conditions extend only to the mouth of the Minnesota, below which the valley widens again and the rock-bluffs resume the same drift-covered aspect as described above the mouth of Bassett's creek.

Throughout this area the layers are nearly horizontal, but in the immediate vicinity of the falls, on the east side of the river, there is a gentle dip toward the southeast. At the falls it amounts to about an inch in one hundred feet; it increases soon to three or four inches in one hundred feet, and at Central avenue it is about five feet in one hundred feet. This dip, however, may not be due to an original inclination in the Trenton itself but to the undermining action of the old gorge or re-entrant angle already mentioned causing a slight downthrow in that direction. Whatever its cause it is but local in its effect, for the position of the beds at points further north, on the east side of the river, is such that they must rise again gradually, or by a fault, to their normal elevation.

The intimate connection which the features and the position of the Trenton areas bear to the history of the recession of the falls of St. Anthony, and hence to that of the drift itself, has induced a careful inspection of the edges of these areas about the falls of St. Anthony, and some further allusion to this formation will be found under the head of *the drift* in Hennepin county.

THE CRETACEOUS.

The great abundance of fragments of the Cretaceous in this drift throughout the county makes it very probable that strata of this age underlie a large part of the county. They are most likely to be continuous in the western and northwestern portions. The only known outcrops that are referable to the Cretaceous consist of coarse sandstone, or conglomerate. One such exists in the bank of Crow river, sec. 18, Hassan, and has a strong resemblance to a coarse drift crag, and was so reported in 1876. Other discoveries, however, by Mr. C. L. Herrick in the banks of Crow river, and a comparison with the well-known conglomerate which belongs near the bottom of the Cretaceous, outcropping in Nicollet and Blue Earth counties, render it very probable that this is a part of the Cretaceous. The projecting layer is about three feet thick, and appears on both sides of the river, running persistently for a distance of thirty or forty rods, dipping a little to the east, causing a terrace in the surface of the alluvium of the flood-plain and rising about eighteen feet above the river. It strikes inland, and is lost under the drift. It has been used by Mr. Hoag for underpinning for his house.

In 1881 Mr. C. L. Herrick, in making zoological collections along Crow river, observed a low outcrop of sandrock on sec. 13, Frankfort, Wright county, and again on sec. 8, Middleville, where it appears on both sides of the river, rising about two feet above the water. This is probably Cretaceous, but in the absence of fossils, and since some of the Cambrian sandstones might also appear there, it is not demonstrated. This is a gray sandstone, somewhat pebbly. Though consisting mainly of pure siliceous grains, it is sprinkled liberally with grains of other colored rock, such as chert of different colors, and apparently a fine-grained diabase of a dark green color. Its general facies is quite different from any Cambrian sandstone known in the state, and strikingly like that containing angiospermous leaves on the Minnesota river in Nicollet county.

There is no portion of the county in which pieces of lignite from the Cretaceous have not been discovered; and throughout the rolling area, where the drift is a close clay, the color of the whole mass is frequently perceptibly tinged with green. Not infrequently pieces of green shale a foot or more in diameter are met with along the cuts by the roadside, particularly in the western part of the county—disintegrated and ready to separate on the least disturbance. These of course could not have been far transported by the drift forces. The drift itself is greatly thickened by Cretaceous debris, and *is conspicuously free from foreign stones and boulders of a more enduring nature.* No other Cretaceous debris than pieces of green fissile shale and of black lignite has been recognized, and from these no fossils have been taken.

Some years ago there was some excitement in the vicinity of Daytou over a reported discovery of coal, about two miles west of the village, in Wright county, by a man named Charles Williams. Upon visiting the place, the excavation was found to consist of two shafts sunk in the drift, now nearly refilled. About the place the drift thrown out shows nothing but drift clay with pebbles of all kinds and colors. One shaft is said to have been about eighty feet deep. There is certainly now no evidence of the existence of coal, or lignite, in the vicinity, though there are traces of the Cretaceous in the drift which points to the near proximity of its layers. There is also a reported exposure of "slate" in a ravine a mile or so beyond, but it could not be found.

The drift in Hennepin county.

In the study of the drift the recession of the falls of St. Anthony comes under review, involving data which serve to throw light on the length of time elapsed since the last epoch of cold.

The till. It has been stated already, in describing the subsoils of the county, that the gray till occupies the greater part of the county, and that the red till is found only in the southeastern one-third. The boundary line which separates these tills at the surface cannot be given with exactness, but its approximate direction is shown on the accompanying map of the county. The gray till had its source in the northwest, and the red in the northeast. Their relative position shows a somewhat later deposition of the gray, along the line of contact shown on the map, since the gray nearly always overlies the red. This difference of time, however, seems not to have been great, but rather such as would be incident to the temporary shifting of the transporting agents under local circumstances. The origination and transport of the two tills may be considered practically contemporary, as a totality, and due to the same general agent. Moreover, the gray till is not always found overlying the red. The two sometimes are mingled, and their color and composition, so far as they are characteristic of either, are lost. Sometimes several thin beds of gray till, somewhat modified by water, are seen to alternate with as many of the red. Sometimes patches of the gray are thrust over on to the general area of the red, isolated from the main mass of the gray. There is quite an extensive area of this, much mingled with gravel and sand, in southern Minneapolis, and in Richfield, southeastward from lake Harriet. But a single instance is known of the gray till underlying the red. This is at the railroad cut near the Inglewood and Glenwood springs, S. E. ¼ of sec. 20, Minneapolis. It here lies below a red till and gravel, and seems to be the stratum which causes the appearance of the springs along the slopes of Bassett's creek. This gray till, however, may be of older date, the counterpart and cotemporary of the gray laminated clay and till, which fills the valley of Bassett's creek and which when penetrated, as at the Sumner school house, and at the Monitor Plow-works, gives rise to a flow of artesian water. At the latter point, situated in the valley of Bassett's creek, a blue clay, with gravel and stones, was penetrated to the depth of 172 feet, from which rose a copious flow of soft water. This same deep-lying blue clay spreads eastward, across the present channel of the river, and is penetrated by deep wells on the east side of the Mississippi for several miles above the falls of St. Anthony,* giving artesian water. It is very probable that this sheet of blue clay antedates the operations of the last epoch of cold, and therefore demonstrates that a former epoch had carried the blue till further east in this latitude than the last one did.

As to the origin of the different tills, they are ascribed unhesitatingly to the disrupting and transporting action of the ice of the glacial epoch on the underlying rock. The blue till is due to a large ingredient of Cretaceous debris, and the red to the red shales of the Cupriferous formation. The former prevails toward the west, and the northwest, and the latter toward the north and northeast. The general movement was toward the south, and, secondarily, toward those valleys of drainage which had a southerly direction. The tills, however, generally are not far transported. They are apt to show a very close relation to the rock that locally underlies them. This is not true so markedly of the modified products of drainage from these tills, nor of the less perishable stones embraced in them. The laminated clays are carried by suspension in water often many miles from the till sheet that supplied them, and the "traveled rocks" of the drift can be traced sometimes a hundred miles

* See the report on Dakota county for similar supposed outliers of an old sheet of blue clay in Marshan.

back to their sources. Such may have suffered the transporting action of several drift epochs; but a characteristic till can hardly exist many miles distant from its source. Hence the existence of a markedly characteristic till very strongly points to the near existence of the rock that supplied its clayey ingredients.* The influence of the great drainage valley of the Mississippi, causing a tendency of all drainage toward itself, including the great body of ice and moving material lying toward the west, seems to have caused the marginal projection of the blue till and its products further east, in the eastern part of Hennepin county, and over the western margin of the red till. These instances occur on the west side of tho Mississippi, while on the east side they are either unknown or rare, or else the position of the tills is reversed, the red till and its products being projected over the blue till, at least over a blue till which spreads widely in the eastern part of the city limits, but which may be, as already intimated, of an earlier date.

Gravel and sand. As there are two kinds of till, one blue or gray, and the other red, so there are two kinds of gravel and sand, the result of the washing of these tills. As the two tills are sometimes mingled so that they lose their characteristic color and composition, or are seen to alternate locally in somewhat irregular sheets or deposits, so the two sorts of gravel and sand are often blended in one, or alternate in distinct layers. When the till was being deposited, the gravel and sand was also being transported and spread in the valleys, the power of washing and of transporting being in proportion to the volume of the water discharged, and the nearness of the ice margin which supplied simultaneously both the water and the drift material. The shifting of the ice, the filling up of old gorges in the rock, the excavation of new ones, the releasing of waters held back in lakelets, the varied incidents which accompanied the marginal recession of the ice-sheet over a rock surface, modified, further, by the climatal changes of the years and of the seasons, can all be appealed to to explain such a mingling of different drift elements, or their alternation, at such a place as the falls of St. Anthony, and elsewhere along the Mississippi, on the supposition that the different tills were being supplied simultaneously.

There is an extensive sandy plain, underlain by coarser gravel and sand, and at greater depth by till, stretching along the Mississippi, on both sides,

* Compare, however, vol. i, p. 628.

through the whole extent of Hennepin county. Its limits are shown on the plate of this county. A similar terrace accompanies the Minnesota. The hight of this terrace above the present river, at low water, can be given at some points, viz.

Crossing of the Chicago, Milwaukee and St. Paul railway and Minnehaha avenue (below the falls),	124 feet.
Opposite the university (which is below the falls of St. Anthony),	128 feet.
Crossing of the St. Paul and Northern Pacific railroad and University avenue, near the university (below the falls),	107 feet.
Depot of the Chicago, Milwaukee and St. Paul railway, on Washington avenue,	25 feet.
Crossing of the St. Paul, Minneapolis and Manitoba railway on Nicollet island, elevation at the old East Minneapolis station,	35 feet.
Crossing of the St. Paul, Minneapolis and Manitoba railway, elevation of the old West Minneapolis station,	32 feet.
Crossing of the St. Paul and Northern Pacific Ry, and Twenty-fourth avenue, N. E.,	56 feet.
The crossings of the streets by this railroad in N. E. Minneapolis are from	45 to 50 feet.
At the old brick and pottery works, in upper St. Anthony; elevation of the brick-clay terrace,*	25 feet.
Champlin (banks of Elm creek),	43 feet.
Dayton,	55 feet.

This plain is limited on the east side of the river by a bluff of gravelly till which rises about one hundred feet with an undulating but rather abrupt ascent, and at the distance of about half a mile further east sometimes rises fifty feet or more still higher. On the west side, the western limit of this plain is much less abrupt. The change from the flat land to the undulating or hilly area of till introduces no sudden transitions. The till area subsides through a series of low knolls down to the level of the plain. The till area is generally timbered and rolling; the flat is generally nearly treeless.

This terrace is itself undulating in long swells, and is crossed by narrow channels which are excavated below its surface uniformly, like old river courses. While it is evident that the Mississippi's waters once had dominion over this flat, and that it constituted the bottom of the river at that time, yet there are places where the superficial light sand, the residuum of that high-water stage, is very thin or is wanting, and the underlying glacier-born gravel rises to the surface. Along the outer margins of the plain, also, the deeper-lying till-sheet appears in knobs above the surface of the plain. The larger upward undulations in this plain, one of which is occupied by the grounds of the university, were produced by the existence of some persistent members of the drift-sheet in greater thickness at such places. At the university there is a considerable

*The brick-clay terrace constitutes a lower flat, set off rather distinctly from the general level of the old alluvial plain, lying near the river, and marked out by a subordinate bench-line. This lower flat is sometimes nearly a mile wide in the northwest part of St. Anthony.

thickness of red till which lies directly on the shales of the Trenton. Over this is a considerable thickness of coarse gravel. This is all screened by an alluvial deposit of light sand from three to six feet thick.

Detailed observations on the drift in Hennepin county.

At a number of places the bedding and alternation of the different parts of the drift have been sketched, and from these sketches the following figures have been drawn. The series of figures which follows (figs. 17 to 20) were taken from the cut of the St. Paul and Northern Pacific railroad which runs along the south side of the university grounds. The cut passes through an upward undulation of the foregoing described terrace-flat, at this place, and is about thirty feet deep at the places sketched. It extends from east to west, terminating at the bluff of the Mississippi river. The first figure represents the composition of the north side of the cut near State street at a distance of about 650 feet from the river; the second at a point about 100 feet further west; the third at a point about 200 feet still further west, and the fourth near the west end of the cut, about 300 feet still further west. These each represent an area on the north side of the cut about thirty feet square.

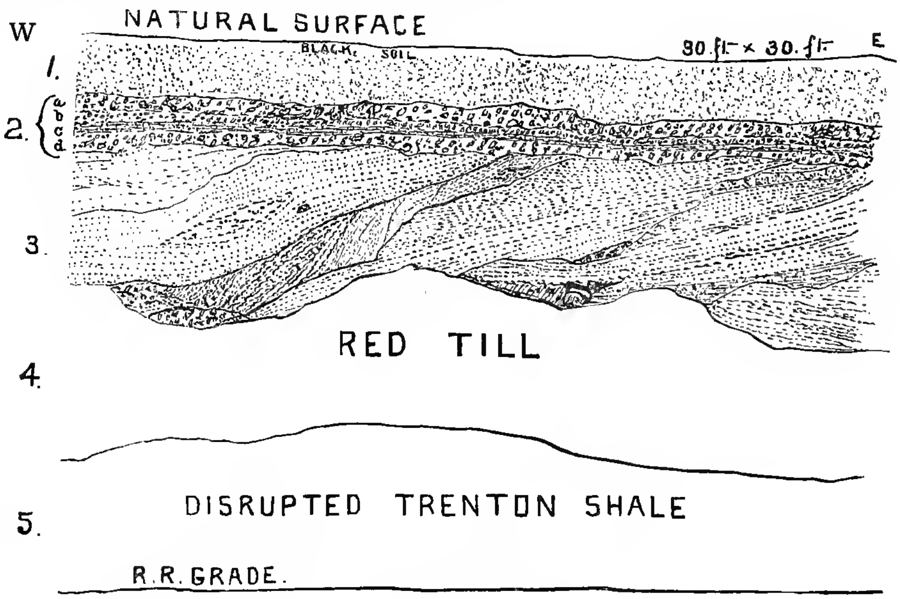


FIG. 17.

Explanation.

1. Loam, sandy, not distinctly stratified, alluvial, 5 feet.
2. Gravel and sand: *a*, pebbles and stones, 1 foot; *b*, gravel, $\frac{1}{2}$ foot; *c*, red, clayey sand, $\frac{1}{2}$ foot; *d*, stones and gravel, 1 foot, 3 feet.
3. Fine red sand, with an occasional pebble of an inch in diameter, with lenticular stratification, sometimes interbedded with coarser materials, with wedging or vanishing western limits. In this is an occasional large boulder, 6 to 10 feet.
4. Red till, tough and characteristic, 8 feet.
5. Blue, or greenish-blue Trenton shale, disrupted, 8 feet.

The super-position of the strata of No. 3 is such that it shows a supply of material from the east or northeast. It all dips toward the west, both the grand layers which wedge out sharply on the west, along their lower side, and the finer laminations of the strata, the latter being cut off by the late super-imposed beds, the lowest laminations being longest intact.

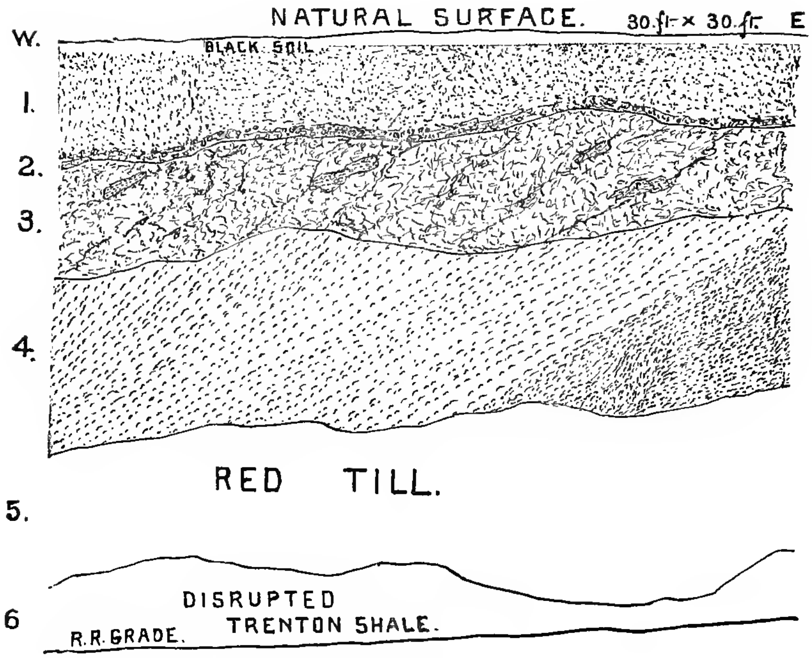


FIG. 18.

Explanation.

1.	Loam, alluvial, not distinctly stratified, black on the surface,	4 feet.
2.	A few water-worn stones and boulders, mingled with clay, rusty brown,	½ foot.
3.	An unassorted, oxidized, pebbly, rarely stony clay, embracing nodules (lenticular) of gravel evidently stratified, but not itself showing at this place any evident assortment. This is not red, but limonitic yellow. This layer comes in obliquely downward like all the rest, from the east, overlying unconformably the strata below, -	9 feet.
4.	Uniformly stratified oblique layers of reddish gravel and sand,	8 feet.
5.	Red till, containing some pieces of foreign, or Winnipeg, limestone,	5 feet.
6.	Disrupted Trenton shale,	4 feet.

A little further west No. 3 changes so as to reveal the action of water in its deposition, the lenticular strata increasing and pervading nearly the whole of it. It is, however, loamy and sandy when this change first appears, the stones which at first were seen distributed through it hap-hazard, not appearing except at the bottom. This semi-stratified condition, increasing upon No. 3 toward the west, passes across the whole stratum in the space of 100 feet, and gives place on the top at first to a stony gray (i. e. limonated) till which also at first shows some stratification, and finally becomes No. 3 of the next sketch.

FIG. 19.

Explanation.

1.	Alluvial, sandy loam,	3 feet.
2.	Gray gravel and sand, less uniformly stratified, containing many stones, the dip in some places being very slight, generally toward the west, rarely east, really probably about south, and hence not visible on an east and west cut,	10 feet.
3.	Gray till, with some stratification. This is not the gray till of the west generally, but is limonitic and yellowish gray, resembling some of the water-deposited pebbly clays of the river valleys,	10 feet.
4.	Fine, reddish stratified sand, -	2 feet.
5.	Red till, embracing some disturbed Trenton shale,	8 feet.

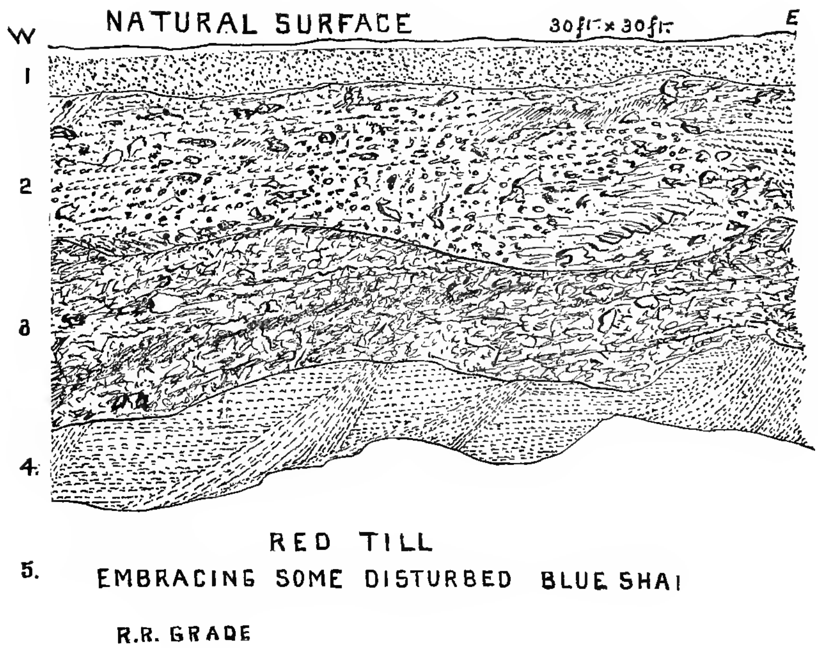


FIG. 19.

In No. 5 there is an embraced layer of transported, much-broken blue till, which also descends southwestwardly. Also the uppermost portion of the Trenton shale is upturned and broken, without long transportation. This all seems to imply powerful, bulky erosion, by some force not water, and rather indicates that glacier-ice is a powerful agent of erosion.

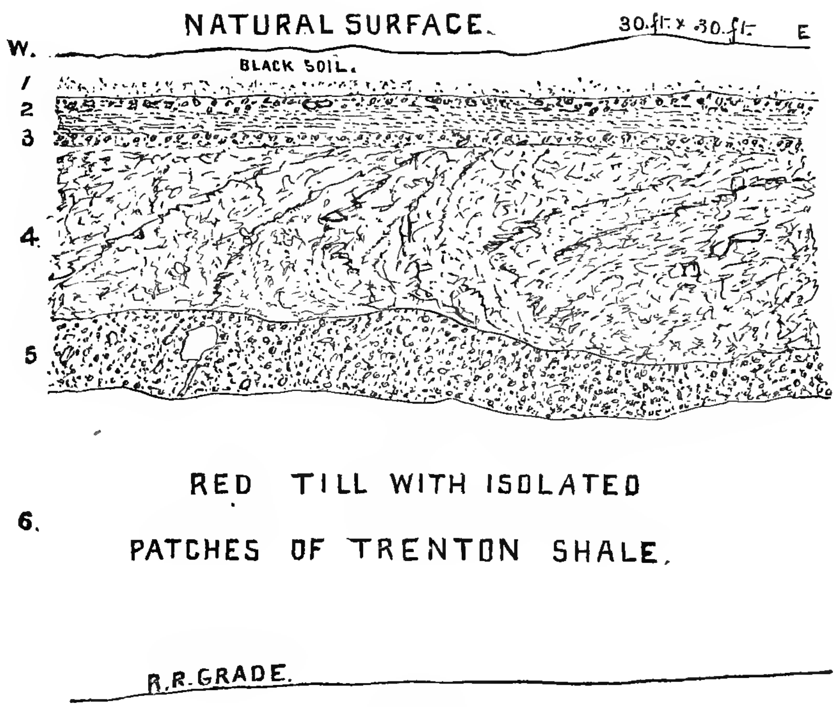


FIG. 20.

Explanation.

1. Black sandy loam, - - 3 feet.

2.	Gravel and stones.	½ foot.
3.	Loamy and indistinctly laminated,	2 feet.
4.	Stones and dirty gravel,	½ foot.
5.	Limonated till, containing rounded pebbles,	9 feet.
6.	Stones and gravel, unassorted,	3 feet.
7.	Red till, containing isolated and somewhat transported patches of broken shale of the underlying Trenton, -	12 feet.

Even in this red till can be seen slight traces of the action of water, in the form of contorted, small nodules and patches of sand.

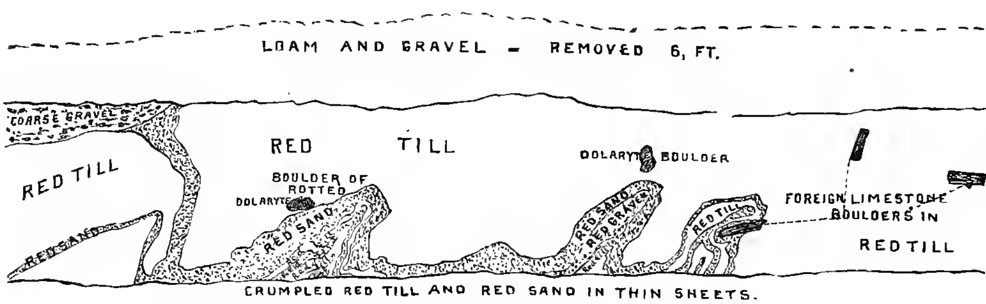


FIG. 21.

Composition of the northeast wall of a cellar, corner of First avenue S. and Second street, Minneapolis.

The section illustrating the composition of the northeastern wall of a cellar at the corner of First avenue South and Second street, Minneapolis, shows two facts which should have a bearing on the interpretation of the method of the grand progress and the causes of the transport of the drift. 1st, the red till carries large masses of the well-known foreign or "Winnipeg" limestone. This indicates either that the limestone formation that furnishes these masses exists to the northeastward from Minneapolis, or that the red till is not far transported, the latter being the most probable. 2d, the deposition of the red till was interrupted by periods of water-wash, and became interstratified with several beds of fine red sand. These alternating thin beds of sand and till were subsequently jammed laterally and thrown into folds and contortions that simulate the anti-clinal and the synclinal overturns of the strata of archæan rocks.

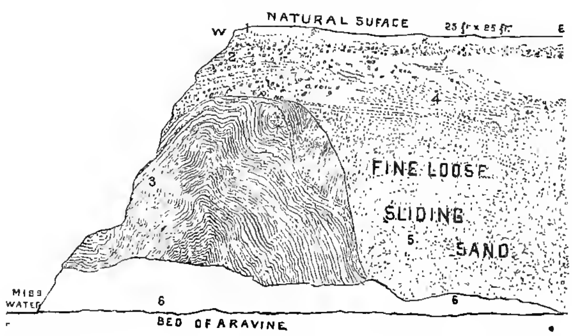


FIG. 22.

Left bank of the Mississippi in upper St. Anthony,—showing the contorted condition of the Brick-clay.

Explanation.

1.	Loam and black soil,	2 feet.
2.	Gravel and sand, rusty, some of it resembling a bog ore gravel,	4 to 6 feet.
3.	Jammed strata of brick-clay. Generally this clay is in horizontal laminations,	15 feet.
4.	Drift sand, apparently giving rise to the sand of No. 5; obliquely stratified; seen,	4 feet.
5.	Fine, loose, sliding sand,	12 to 15 feet.
6.	Talus and water-slope, composition not known,	4 feet.

This broken and crumpled condition of the brick-clay strata seems to indicate the same agent as that which tore up and contorted some of the red till and red sand strata shown above in figure 21. There is a sudden transition upward into gravel and sand which lie uncomformably over the brick-clay, and graduates upward into sand, and then into the loam and black soil, with which the flat is covered. Singular contortions can be seen in the strata of this clay at the brick yards that are just north of the county line, in Anoka county. Some of them are of a character that can hardly be attributed to the lateral thrust of a pushing mechanical force acting horizontally,* unless it was remittent in its action.

Near the falls of St. Anthony, on the east side of the river, the drift bluff rises about 45 feet above the water, and has been excavated by the United States engineers for material in filling the tunnel which endangered the falls, thus successively revealing different parts of the bank. Since this work was done, and these observations were made, the place has been refilled and entirely worked over for the erectiou of the building of the Minneapolis exposition. A common general section is as follows:

1.	Loam,	3 to 6 feet.
2.	Stones and boulders, rounded, some of them glaciated, sometimes with a considerable thickness of sand,	5 to 15 feet.
3.	Red till, with stones and boulders, lying on the rock,	10 to 20 feet.

In a few places along this excavation the color of No. 3 is not so distinctly red or copper-colored. It seems to be lighter, as if it had been mingled with till of a later date which in much of the county is seen to overlie the red till. This shading of color pertains only to the upper portion of the deposit. There are also places along the same bank where the light-colored or gray till was deposited in considerable quantities, and still remains, and as the bank recedes a little from the river this light-colored till occupies the inner and lower portion of the main slope in such a way as to hide the red entirely, and give a false impression of its having replaced it. In other places it is seen to lie directly on the red.

By further and more detailed examination of the same bank the foregoing No. 2 is seen to become separated into two or three pretty constant parts. It is sometimes clayey, and of a gray color. It is sometimes entirely made up of gravel and sand with belts of boulders, the alternation of all the parts being expressed by the following:

1.	Loam,		3 to 6 feet.
2.	2 (a).	The gray sand and gravel,	0 to 10 feet.
	2 (b).	The gray stones and boulders,	1 to 10 feet.
	2.	The gray till,	0 to 6 feet.
3.	3 (a).	The red sand and gravel,	0 to 10 feet.
	3 (b).	The red stones and boulders,	1 to 2 feet.
	3.	The red till,	10 to 25 feet.

There are three main parts or members. No. 1 is never wanting. No. 2 is always seen as far as this excavation is concerned, but its subordinate parts are not always all present. Very often 2 (a) and 2 (b) are the only portions seen; and in other places 2 (a) is wanting, the only thing that separates No. 1 from No. 3 being No. 2 (b). Of No. 3, the red sand and gravel may be absent, but in no case has the line of red stones and boulders been found wanting. The red till, No. 3, is the most conspicuous portion of the whole, and is always present, rising sometimes by alternations with No. 2 (gray till) to near the top of the bluff. There is in that case always a loam (No. 1) overlying, and a similar mixture of red stones and boulders with gray, immediately overlying the red till. The gray till at this point is quite unimportant as a member of the bank, but it is found to embrace very large boulders, not only of granite, but also of the Lower Trenton formation. Its color is very marked in contrast with the red till. The stones in it have the appearance of glaciation. The red till at this place has not been seen to embrace a piece of the Lower Trenton. Its boulders are usually small, rarely exceeding ten inches in diameter, while the bulk of it has only stones, less than four inches in diameter, and of a red color and quartzitic composition. "Greenstone" as a boulder is also common in the red till. The iron in it, which causes the color, is *peroxide, non-hydrated.* The iron in the gray till is *hydrated.*

The drift surface on the bluffs along the northeast side of the river, at Minneapolis, shows no gray till. The bluffs rise about one hundred feet, average, higher than the top of the foregoing section and consist, so far as seen, of red clay and gravel. Toward the southeast, where the St. Paul, Minneapolis and Manitoba railway. passes out of the valley of the Mississippi, the characters of the gray and red are mingled at first in an overlying stratum of gravel and sand, but before reaching St. Paul the gray has entirely disap-

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* Dr. Edward Hitchcock, in 1833, observed similar contortions in the "Tertiary" clay at Deerfield, Mass., and has figured the laminæ in his *Report on the Geology, Mineralogy and Botany of Massachusetts*, pp. 173–75. Similarly contorted bands are illustrated in the volume giving the geology of the crystalline rocks of Minnesota.

peared so that in the bluffs at that place the drift is all red clay, or sand, gravel and boulders derived from red clay, the whole having a characteristic prevailing red color.

At three-quarters of a mile below the university the section of the left bank of the river not including the outer bluffs is expressed by the following:

1.	Loam,	5 feet.
2.	Gravel and gravelly clay,	20 feet.
3.	Red till, to the rock; perhaps,	15 feet.

Below the falls on the west side of the river the till that appears in the bluff of the river is usually gray, containing boulders of granite and fragments of limestone, varying somewhat irregularly upward to gravel and stones in oblique stratification, or without stratified arrangement, amounting altogether to about twelve feet in thickness, not including the alluvial loam which is from three to six feet thick.

At the corner of Washington avenue and Sixth avenue North, Minneapolis, the following section was exposed by the grading of the streets. It is situated near the descent to Bassett's creek, on the south side of the creek, where the Trenton limestone has been broken down, and over the St. Peter sandstone. The waters of that stream probably had something to do with the sudden transition here seen from sand to brick-clay. Although there is at one point in this cut an agreement in direction between the strata of the sand and those of the clay, on close inspection it appears that the clay came on suddenly.

1.	Loam, stratification not evident; apparently passing downward into brick-clay,	2 to 4 feet.
2.	Brick-clay,	1 to 4 feet.
3.	Fine sand, lying unconformably under the last,	1 to 4 feet.

No. 1 contains calcareous concretions as large as peas and walnuts. It cannot be said to merge certainly into No. 2, but it seems to. The stratification of No. 2 fades out gradually upward, while the texture and composition continue somewhat into No. 1, becoming also yellow, or at last rich brown or black when it is termed soil. No. 2, as seen in this exposure, consists of a long synclinal, the axis running nearly north and south, toward the west, so lifted as to disclose what it lies on, (No. 3.) It is quite calcareous, showing concretionary lumps, and coatings, and also at a point on Fifth street, fresh water species of shells—though the cut there may be more nearly the equivalent of No. 1. This section shows that the source of the water which spread the brick-clay was toward the west, and that the bottom on which it was spread was one of stratified fine sand which increased toward the west.

At the brick yards which were formerly operated in the valley of Bassett's creek, situated south of the creek, that which was known as the Union brick company's yard was but a short distance west of the section last described, near the intersection of Third avenue North and Sixth street. The clay here used is light-colored, with some beds of fine white sand to the depth of about eight feet, when it begins to be blue. Upward it becomes a clayey loam. The layers have a wavy outline, synclinals and anticlinals following each other twice in about fourteen rods, rising and falling six feet.

At another yard, about half a mile further west, yet within the low ground of the valley of the creek, the clay is underlain by a quick-sand which furnishes water that rises to within twelve feet of the surface. The clay is about forty feet in thickness, and contains thin layers of sand, interlaminated, which becomes white on drying, evidently derived immediately from the St. Peter sandrock. The upper portion gradually becomes yellowish by exposure and the hydration of the iron, the lower portion being blue.* There are also in it calcareous concretions and a few large Unio shells which are very fragile. This clay seems to occupy the valley of Bassett's creek generally in this part of its course. At the Sumner schoolhouse, which is in the same valley, after drilling through this clay, over one hundred feet, an artesian overflow of water was obtained.

In Highland Park, Minneapolis, in a region of red till, some pieces of foreign limestone can be seen, on elevated morainic surfaces, some of them being three feet by two feet in dimensions.

In Crystal Lake, N. W. ¼ sec. 8, (S.) the following section was observed at the highway:

1.	Gray, or yellowish till, with a few Cretaceous pieces and some boulders,	8 feet.
2.	Red till, passing into red sand and gravel below,	6 feet.

The red changes to the yellow, or hydrated, gray till by a series of blotches, interchanging one with the other as if coarsely mixed. Even between the blotches there is a sudden change of color. When the line of union is not broken up into blotches the change of color is abrupt. The gray till is

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* This is the conventional remark, the supposition being that the whole of the clay, or the till, under consideration, was at first blue, and that the change of color has been toward the yellowish tint by the natural process of hydration and oxidation. But there are some considerations that go to show that the progress of change in color has been exactly the reverse—or from the yellowish gray, hydrated, state to the blue the chemical change being one of deoxidation downward.

more calcareous than the red. The appearance of the red is such as to indicate the existence of a lake, or at least a low spot in its upper surface, prior to the deposition of the gray.

The drift knolls at Wayzata are of gray till, rather gravelly, but occasionally show the red till at low levels where cut by the roads.

Near the mill at Minnetonka City the red drift can be seen in a little excavation by the road, on a level with and near the creek. It is overlain by a course of stones and gravel, in which appears a piece of the Trenton, and that again by the great deposit of the gray till generally over the country.

The ridge which enters the corporate limits of Minneapolis (sec. 27) is a spur from the main drift-bluff running along the west side of the river. The most of it, within the limits of the city, is of gray gravel, with variations toward the west and northwest toward the red till, of which there is a considerable area extending to and beyond Cedar lake. The northwestern portion of this ridge, where it swings to the west, and forms the southern bluffs of the valley of Bassett's creek, shows a liberal intermixture of stratified gravel and sand derived from the red till. Numerous sudden alternations are apparent between red sand and fine clay, and gray sand and clay, some of the gray clay being rather a pebbly clay than a boulder clay. The abrupt descent to the valley at Central Park, and to Bassett's creek, gives this elevation a greater apparent hight from the east, and affords a very good prospect over all that part of the city lying within the immediate valley of the Mississippi. Toward the west the descent is less, a part of the ancient terrace-flat of the Mississippi spreading to Cedar lake and lake Calhoun.

From Parker's lake, all the way to Minneapolis, pieces of foreign limestone are occasionally seen in the drift, the region being one of red till.

Section 36, *Champlin*. The rolling land begins gradually, the timber showing a corresponding gradual transition. The rolling land is stony, clayey or gravelly, with patches of sand, as revealed in wells, with some patches of stratified clays, near the flat land. The stones are mostly granitic, but have among them also numerous large masses of light-colored, fine-grained dolomite, which are burned for quick-lime. Water is obtained easily in wells at about forty feet, sometimes at fifteen or twenty.

At the mouth of Elm creek, near the village of Champlin, the bank is exposed by the action of the creek, disclosing the composition of the plain on which are Osseo and Brooklyn. The upper portion of the bank, including the loam, is 18 feet, and consists of coarse sand, with gravel and pebbles obliquely stratified, the whole of a light brown color. The lower portion—25 feet—consists of red till which continues down to the level of the water of the Mississippi.

In traveling the river road from Champlin to Dayton, a very noticeable change occurs in the nature of the surface drift, before reaching the latter place. It becomes lighter colored, slaty or ashen, with pieces of slate. About a mile below Dayton a large freshet wash by the roadside, where a creek enters the Mississippi river, shows an exposure of about 35 feet of pebbly clay of a light, gray color, with pieces of slate, and an occasional boulder near the bottom, underlain by a sand of the same color, 20 feet thick, varying to very fine or clayey, stratified, which, washing out easily causes the downthrow of large masses of the clay, both in the creek gorge and along the river-bluff. No red till is visible, the surface about being rolling, with occasional boulders.

At Dayton the general character of the surface shows the gray, or ashen, slaty, rolling till. Along the banks of Crow river the drift is exposed in a good section.

1. Stratified fine sand and clay,	10 feet.
2. Blue till,	25 to 30 feet.
3. Red till,	8 to 10 feet.

In No. 2 are many fragments of Cretaceous slate, lumps and scales of oxidized siderite, irony concretions covered with gravel and cemented by iron-rust, granitic pebbles, and masses of limestone. The last have supplied the town with a great deal of quick-lime. In No. 3 are a great many small greenstone, and quartzitic stones, as well as numerous others of granite. But few of these are large.

A piece of metallic copper was found in the debris of the river bluff at Dayton, about the size of a hickory nut, some years ago, by James Ream. This probably was washed out from No. 3 of the foregoing section.

On section 12, Crystal Lake, near the mouth of Shingle creek, in digging a well for Mr. J. Kesler, Mr. O. E. Spear found a stick as large as his wrist in a blue clay, (the brick-clay) that had no stones nor gravel, about 18 feet beneath the surface.

On the N. E. ¼ sec. 12, Crystal Lake, at Peterson and Swansen's brick yard, this same clay is manufactured into cream-colored brick. It is obtained in the immediate river-bank, and runs apparently beneath the river. It is blue, stoneless and horizontally stratified.

N. E. ¼ *sec.* 12, *Crystal Lake.* At a short distance above the mouth of Shingle creek, the right bank of the river is largely composed a blue clay which is finely laminated, and is extensively used for making brick of which it supplies th quality known as "Milwaukee brick," being of a light cream-color. The section here is as follows:

1.	Loam,	3 feet.
2.	Sand, gravel and pebbles; stratified, sometimes rusty,	4 to 6 feet.
3.	Brick-clay; blue and horizontally bedded,	15 feet.
4.	Slope to the river; apparently clay,	15 feet.

An ideal section of the right bank of the river at this place would be shown by the following diagram. This is based on observed exposures of the various parts in such topographical positions as to indicate its correctness.

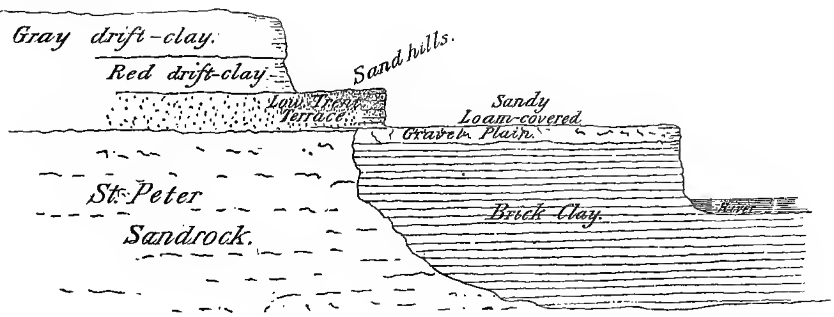

FIG. 23.

Section of the right bank of the Mississippi near the mouth of Shingle creek.

The above figure represents the brick-clay as lying immediately on the St. Peter sandstone, because at that point no drift-clay can be seen to lie between them. It is more probable, however, that a deposit of drift clay, perhaps both the red and the gray, runs below the brick-clay, as seen at St. Paul; or at least that such a deposit antedated the brick-clay, though subsequently perhaps entirely swept away.

About the lakes (Mother, Amelia, Calhoun, etc.,) the country is rolling, but is less so toward the southeast part of that tract; indeed the rolling area gradually dies away into the plain in some parts of Richfield so that its eastern margin is not so marked. On the plain the soil and the subsoil is gravelly or sandy, very rarely stony. The same is true of the rolling tract about Diamond lake. There are no stones in the fields nor about the lake shores. This seems to indicate the agency of water rather than of ice in piling up these outer knolls, and in spreading the gravel of the plain. Minnehaha creek has a gravelly bottom all the way below Richfield, at least.

At Richfield P. O., Minnehaha creek runs about 35 feet below the general level of the country, and the banks are composed of gravelly, gray or yellow clay. No red clay can be seen. But at the school house in Richfield, sec. 18, on Minnehaha creek, the well, dug, disclosed the red drift clay some feet below the surface. At the Edina mills there is a bank of drift, composed of clay and gravel of the usual gray color, containing many pieces of the Trenton limestone.

In sec. 16, *Eden Prairie*, a cut by the road shows the red drift, on a low level, but five or six feet above the creek, while in the higher portions the gray only is seen.

Through sections 20 *and* 19, *in the southern part of Bloomington*, the hardpan drift, on the north side of the Ferry road, rises above the flat on which the road runs, with the appearance of a terrace, and is wooded with oaks, aspens and ironwood. For some distance the terrace-like level on the surface of the hardpan is about half a mile north of the road, and rises about 40 or 50 feet. It is stony with occasional boulders, becoming more rolling further north.

At Bloomington Ferry the river runs near to the hardpan bank on the north side. The bank rises 140 feet above the water in summer. This is about the average, the top of the hardpan being of irregular outline. This includes the "terrace" of hardpan mentioned in sections 20 and 19. That terrace appears to approach the river here. The surface further back is still higher, and indeed continues to ascend with an irregular contour. The hardpan is yellowish brown or gray, and gravelly near the top, but also has afforded some large granite boulders, that now lie in the street near the ferry, and others that are on the beach below the erry. The Minneapolis and Chaska brick-clay is seen also at the ferry, and some years ago supplied a red brick seen in the house of Mr. Chadwick. Within a mile and a half, toward Eden Prarie, the surface rises apparently about 100 feet higher.

In the valley of Purgatory creek, sec. 4, Eden Prairie, are pieces of northern limestone, one of them measuring four feet across. The region is one of gray till.

On the direct road to Wayzata from Minneapolis, the line between the gray and the red tills is about at the section line between sec. 7 of Minneapolis, and sec. 12 of Minnetonka; but the transition is not abrupt. There are a great many intermediate phases, with gravelly patches that cannot be referred certainly to one or the other.

One and a half miles south of Excelsior are gray till hills that rise more than a thousand feet above the sea, or about one hundred feet above lake Minnetonka.

About the west end of lake Minnetonka the drift is very clayey and has a great proportion of the Cretaceous materials. The water of wells is very hard.

On sections 35 *and* 36, *Minnetrista*, are gray till knolls that rise 1050 feet above the sea. The gray till here is not so clayey at the surface, but more stony, with occasionally a piece of northern limestone. A farmer here, by the name of Joe Smith, has built a two-story house of such stones.

All the way round the lake, from Excelsior to Maple Plain, nothing can be seen but gray till, very rough and rolling everywhere except at the northwest in the vicinity of Maple Plain, where it is more nearly flat.

The southwestern part of Independence is undulating, or flat, compared with Minnetrista, and this kind of surface continues to Delano, in Wright county, and into the north and northwest part of Independence, except in the vicinity of lakes.

In traveling the Corcoran road westwardly the soil changes from gray clay and loam to sandy loam gradually, about on sec. 34, Maple Grove, and sec. 2, Plymouth. Elm creek, on sec. 29, Maple Grove, is 50 to 60 feet below the general level.

The highest drift knolls in the neighborhood of Minneapolis are in Anoka county, about sec. 24, Manomin, in the neighborhood of Sullivan's and Moore's lakes, but east of them. They are of red drift clay, with gravel and granitic boulders, yet *the boulders are not so common* as might be expected. The soil is clayey, and loamy, but between the bluffs and the river are extensive sandy flats. Little wet spots, even lakes and swales which never become dry, lie between these knolls. These hills continue S. E. toward Bower's lake in Ramsey county. The high hill north of and near Bower's lake is 130 feet higher than the N. E. corner of Moulton's nursery, which may be taken as an average hight for the drift bluffs along the east side of the river. From the nursery to the foundation of the university is a further descent of 110 feet; thence to the river at the university 137 feet, making a total descent from the high knolls at Bower's to the river below the falls, in the rapids near the university, of 377 feet.

Minnetrista kame. On secs. 16 and 9, Minnetrista, is a curious narrow ridge, simulating a kame. It runs between Long and White Tail lakes. It is from seventy-five to ninety feet high, above the adjoining waters. Unfortunately no place could be found where the composition of this ridge could be seen with any certainty, although in some places along the road which runs on it, some gravel and cobble stones could be seen. Its surface is the loam with which the country here is covered, and the soil sustains large trees, such as oak and maple. At its southern end it spreads out so as to disappear in the general till area. Toward the north, in the same way it becomes wider and lower, with an undulating outline. It is so narrow in some places that there is room only for the road along the crest; its upper surface also rises and falls ten to twenty feet in passing from its northern to its southern end. It occasionally has a boulder exposed in the road.

This ridge also runs along the northwest side of sec. 10, east of the highway, and into sec. 3, but is lost in a generally rolling area before it reaches the Watertown road. Along the west side of sec. 10, though the general level of the road is 1000 feet, the ridge is perceptible running north and south, rising about twenty feet still higher.

Some of the short morainic ridges in the northeastern part of Eden Prairie, in Minnetonka and in the western part of Minneapolis, are isolated, consist of gravel and sand, with some boulders, and have somewhat the appearance of kames; but they do not show that continuance and uniformity of direction that are seen in such ridges as that in Minnetrista, and in Bridgewater, in Rice county.

Fossils in the drift. Besides the remains of wood, which indicate an interglacial forest covering the surface of Hennepin county, found at numerous places in the county, Mr. J. G. Sommers discovered the remains of the extinct American beaver, *Castoroides ohioensis*, Foster, in the gravelly plain that borders the river at Minneapolis. It was in the process of digging a cistern, and about eight feet below the surface, at the corner of Fifteenth avenue North and Washington avenue, that this discovery was made. The specimen preserved consists of the left mandibular ramus. It was situated near the upper surface of the brick-clay with which the gravel of the plain is underlain, in that part of the city.* Accompanying it were fragments of *Unio* shells. It hence belongs to that period of time when the Mississippi extended between the high drift bluffs that enclose the city of Minneapolis, separated about two miles, and hence to the flood or "terrace" epoch of the glacial period. Probably the last glaciers still prevailed over the northern part of the state, their dissolution supplying the abundant water and detritus which characterized the Mississippi at that stage.

Wells in Hennepin county.

The county is well supplied, at slight cost for digging, with good water for all domestic uses. The following facts were obtained in the survey of the county by means of inquiries made for finding out the distribution of the various parts of the drift.

Hassan. De Puy; sec. 12: well, 12 feet deep, entirely in clay; water seeps from the clay.

Dayton. A. J. Roe (Maple Grove P. O.); well, 13 feet, found numerous pieces of coal; and at another point three-fourths of a mile distant, an eight-inch well auger brought up nothing but coal at a depth of forty feet.

Champlin. Wells at Champlin village generally find good water at 25 to 33 feet. At the Fonduck House good water was found at 8 feet above a "dark clay," the well being 33 feet deep. Matthias Zopli; sec. 36: well, 20 feet deep; water rose ten feet. William Schmidt; sec. 36: well, 45 feet, on a sandy knoll.

* This specimen is preserved in the general museum of the university. For a full description of it see the eighth annual report, p. 181.

Greenwood. Many of the wells in this town, especially in the flat western portion, are shallow, and the only water they get is that which seeps slowly from the blue clay. It is hard. In the more elevated rolling tract in the western sections some wells are fifty to seventy-five feet deep.

Corcoran. Hugh Kearn; sec. 26: well, 191 feet deep; clay nearly all the way; water in sand, rising to the top at first, but settled to 91 feet, where it stands. George Cook; sec. 36: well, 178 feet deep; clay nearly all the way; water in sand.

Maple Grove. Ferdinand Schmidt; sec. 1: well, 44 feet deep; stratified clay and sand, 12 feet; good water. Wells generally at Maple Grove are from 15 to 25 feet, in blue clay; no knowledge of any red clay. Joseph Hennesey; S. W. ¼ of sec. 29: well, 16 feet, in clay. Thomas Hennesey; S. W. ¼ of sec. 29: well, 15 feet, in clay. Martin Devereux; S. W. ¼ of sec. 28: well, 65 feet deep; blue clay, water in sand. Robert Cook; S. W. ¼ of sec. 30: well, 164 feet; all blue clay, except 20 feet of yellowish, pebbly clay, with no stones larger than one inch in diameter; no water. Pat. Kelly; N. W. ¼ of sec. 30; well, 117 feet deep; mostly clay; water in gravel.

Brooklyn. All wells in Osseo and Brooklyn get good water from 12 to 14 feet. The country is flat.

Independence. Water is, hard, generally obtained directly from the blue clay by seepage, or from local beds of gravel and sand, the latter often at great depth from the surface. Mr. Cleveland, at Maple Plain, has two wells 15 feet deep; loam, 8 feet; sand and gravel, 7 feet; water stands 8 feet from the surface.

Medina. E. M. Snow; S. E. ¼ of sec. 34: well, 14 feet; mostly sand and gravel; then blue clay, with good water. May and Company; S. E. ¼ sec. 34: well, 60 feet; mostly in till; water irony. Medina mills; S. E. ¼ of sec. 34: well, 175 feet deep; gravel and sand, then blue clay; water soft.

Crystal Lake. C. H. Sanborn; N. W. ¼ of sec. 5: well, 40 feet; good water. Crystal Lake house; S. E. ¼ of sec. 6: well, 40 feet; sand nearly all the way, then clay. Wm. Knight; S. E. ¼ of sec. 10: well, 14 feet; sandy loam, good water. J. Miller; N. W. ¼ of sec. 9 (S. E.): well, 76 feet deep; loam, 1 foot; yellowish till, with stones, 5 to 6 feet, blue-black clay, with no stones nor bedding, having sticks at different depths, and small pieces of Cretaceous lignite, but *positively "no stones."* Small quantities of water were met at 15 feet below the surface, and again at 25 feet, and 45 feet; sand, boulders and gravel, all mixed, with no clay, some of the boulders being very large, 3 feet; light-colored clay, with small stones but no boulders, nothing red about it, 19 feet; mixed stones and gravel, cemented, 1 foot; sand, with water, 2 feet; blue limerock which had a rough surface, not polished nor scratched, 20 feet. John Hooper; N. E. ¼ of sec. 8 (S. E.): this well struck the Trenton limestone. P. Schuler; sec. 18: well, 63 feet; soil and loam, 3 feet; blue clay, 50 feet; quick-sand, 2½ feet; blue clay, 8½ feet; water rose from below a thin scale, which was hard, with such rapidity as to nearly drown the man who was at work at the bottom of the well before he could be rescued.

Minnetrista. Chris. Larson; N. E. ¼ of sec. 19: well, 40 feet; entirely in clay; the surface is a yellowish loam, becoming at the depth of twenty feet a blue clay, entirely pebbly, but not strong. Dr. E. Priest; sec, 23: well, 25 feet; yellow clay, till and sand, giving hard water. Jacob Schleh, sec. 30: well, 36 feet; yellow clay, 18 feet; blne till, with sand and gravel, giving good water, 18 feet. J. Metz; sec. 30: well, 36 feet; yellow clay, 18 feet; blue till, with sand and gravel, giving good water, 18 feet. Albert Moss; on the county line, S. W. ¼ of sec 33 (really in sec. 3, Lake, Carver county): well, 20 feet; clay, 18 feet; sand and stones, with water, 2 feet. Susanna Sanger; S. E. ¼ sec. 34: well, 35 feet; all clay. George C. Phillips; N. E. ¼ sec. 20: well, 55 feet; pebbly clay, 6 feet; sand and gravel, 49 feet.

Excelsior. At the village of Excelsior wells have to go from 100 to 140 feet in gray clay (mostly) before getting water. Consequently there are but few wells in the village, the people depending either on the lake, or on rain-water.

Minneapolis. Mr. Clark; three-fourths of a mile north of Highland Park: well, 68 feet; clay and sand, 52 feet; in limerock, 16 feet. Peter Hill; S. W. ¼ of sec. 4: well, 22 feet; gravel and sand, near a tamarack swamp. David Corban; N. E. ¼ of sec. 12: well, 70 feet; nearly all clay; water in sand, rose 25 feet. N. Palmer; Gale's second addition: well, 45 feet; clay with boulders, 26 feet; limerock, 19 feet. Fred Wagner; No. 1200 North Twenty-third street; well, 44 feet; clay and boulders, 25 feet; limerock, 19 feet. R. S. Lee; Highland Park: well, 27 feet; clay, sand, clay, sand, good water. Lambert Negley; Nineteenth street, between Twentieth and Twenty-first avenues North: well, 45 feet; sand all the way to white sandrock. —— Halsey; Nineteenth street, between Twentieth and Twenty-first avenues North: well, 45 feet; loam and gravel, 37 feet; limerock 8 feet. John Eagle; corner Twentieth street and Twenty-first avenue North: loam and gravel, 20 feet; limerock, 15 feet; sandrock, 10 feet. —— Parker; Christmas avenue and Twenty-third street: well, 48 feet; clay, 39 feet; rock, 9 feet. On the plateau on which the university stands, on the east side of the river, wells are from 25 to 30 feet deep; sandy loam, 4 to 10 feet; gravel and sand, with boulders, 10 to 20 feet; red till, 2 to 10 feet; Trenton shale, 2 to 4 feet; water generally lies on the Trenton shale, or on the red till when it is sufficiently impervious.

St. Anthony. N. O. Phillips; N. W. ¼ of sec. 6: well, 20 feet; water comes from the clay; fails in the dry season. D. D. Moore; S. E. ¼ of sec. 6: well, 40 feet; clay nearly 40 feet, then coarse sand; little water. D. D. Moore; S. E. ¼ of sec. 6: well, 40 feet; no water. Frank Thielen; S. E. ¼ of sec. 6; well, 87½ feet deep; "blue clay," 24 feet; then red clay, sand and gravel, with good water. —— Wilson; Hoyt's addition to St. Anthony: well, 15 feet; all sand; then struck the limerock, which is smooth like a floor.*

Richfield. Jesse N. Richardson; Richfield village: well. 68 feet; gravel and gravelly clay; good water. Henry Richardson; S. W. ¼ sec. 20: Town-hall well, 98 feet; sand and gravel, 92 feet; rock (unknown, but "bluish and rather easy to drill"), 6 feet; water rose, at six feet after striking this rock, 60 to 70 feet in the well. School district No. 17; S. W. ¼ of sec. 18: well, 109 feet; drift, 99 feet; rock, 10 feet. This rock is said to have been similar to that in the well of Mr. Richardson. Frank Paul, S. W. ¼ sec. 31 (E.): well, 75 feet; loam, 40 feet; the rest clay; no rock; no water. Frank Paul; S. W. ¼ of sec. 31: well, 27 feet; sand all the way; no rock; no water. Frank Paul; S. W. ¼ of sec. 31: well, 53 feet; no rock; no water. William Fanchon; N. W. ¼ of sec. 31: well, 57 feet; drift, 46 feet; limerock, 11 feet; then white sand and good water. J. Stansfield; N. W. ¼ of sec. 14: well, 56 feet; some clay; but mostly gravel.

Bloomington. T. Vessey; sec. 5: well, 56 feet; near the river, in the bluffs. F. X. Brusseau; sec. 14: well, 27 feet; sand; near the river bluff; water in clay. John Scofield, 4 or 5 miles east of Bloomington ferry: well, 53 feet; good water. —— Bailiff, 4 miles east of Bloomington ferry: well, 56 feet; first 25 feet all sand. John Brown; near Bloomington ferry, on the river bluff: well, 189 feet; clay and sand, 88 feet; clay, 90 feet; water in gravel, 11 feet.

Eden Prairie. —— Rankin; N. E. ¼ of sec. 17: well, 43 feet; sand and coarse sand; good water. —— Smith; N. E. ¼ of sec. 17: well, 169 feet; unknown, 45 feet; fine, pervious, clayey drift, 100 feet; sand and gravel, with water, 24 feet.

Medicinal springs.

Some of the springs of the county have a local repute for medicinal qualities.

The *St. Anthony Falls mineral springs* consist of a copious discharge of water from the top of the shale layer between the main calcareous members of the Lower Trenton in the bluff of the river. They are situated just below the falls, on the east side of the river. The overlying layer of limerock is parted along some planes and allows the water to enter it, but the shale is nearly impervious, and sheds it. The water is not originally from the rock, but is the drainage from the drift, and the swamp east of the city. It probably derives its iron from the ferriferous drift of the bluffs further east; passes into the swamps, deposits, after evaporation, a considerable iron as a bog iron ore, and carries on what it does not leave in the swamp, penetrating the gravelly and sandy drift between the swamp and the river bank. The iron is deposited as a peroxide on the rock over which the water runs. The taste of the water is very pleasant, and is similar to that of a number of wells, which afford chalybeate water, situated further back from the river and on the margin of the swamp. Although this water is known as chalybeate, from the copious deposit of iron it gives on exposure to the air, yet the quantity of iron present is very small.

On analysis Mr. S. Dana Hayes, of Boston, has said: "When heated it evolves gas; after some evaporation it becomes opalescent, and finally deposits a precipitate, while it becomes more and more alkaline. It has the chemical character, and is strictly an *alkaline mineral water*, resembling well-known waters found in the northern part of Vermont, and in Germany and elsewhere in Europe." Mr. Hayes gives the following analysis: "One United States gallon, or 231 cubic inches, contains nineteen and eighty-four hundredths grains of solid dry mineral matter, consisting of:

Potash,	1.257
Soda,	1.900
Sodium,	.060
Lime,	5.394
Magnesia,	1.589
Ammonia,	trace

* S. H. Baker's well at the mouth of Rice creek, in Anoka county, struck a fawn-colored magnesian limestone at the depth of 94 feet.

Alumina,	trace	
Protoxide of iron,		.028
Sulphuric acid,		.117
Chlorine,		.104
Silicic acid,		.645
Carbonic acid, combined,		8.106
Crenic acid, organic,		.640
Total,		19.840

"These elements are probably combined in the water forming the following salts and compounds:

Carbonate of potash,	Sulphate of potash.
Carbonate of soda,	Silicate of soda.
Carbonate of lime,	Chloride of sodium.
Carbonate of magnesia,	Crenate of iron, etc.

"All the carbonates named exist in the state of bicarbonates; and the gases present are carbonic acid, oxygen and nitrogen; the water containing three and three-tenths volumes of mixed gases in one hundred volumes of water. The aeration of this water renders it a pleasant beverage, and prevents the sense of heaviness after it has been drunk in quantities. Besides the alterative medicinal qualities possessed by this water when taken internally, it will be found beneficial in hot and cold baths, especially in certain cases of skin diseases. And it may be bottled and kept, retaining all its virtues for months without material alteration."

The mineral qualities of this water ally it with those waters that are dependent on the blue till, and such are found mainly on the west side of the Mississippi. In this case these alkaline qualities are attributable to an important deposit of this blue till on the east side of the river extending from the northeastern corner of St. Anthony northward and eastward into Ramsey county. These springs once had considerable patronage as a local resort, aud the water was sold in the city of Minneapolis, but at the present time they attract but little attention. This is largely due to their unfavorable location.

The Inglewood springs are owned by Foster, Bradbury and company, and are situated in the northwestern suburbs of Minneapolis. They discharge into the valley of Bassett's creek. The water is shed by a gray clay which underlies the red till of the region. This clay is visible in the railroad cut near the springs, and is apparently a gray till, but it may be dependent on a shaly deposit of Cretaceous age not far removed. The character of the water resembles that of the St. Anthony Falls mineral springs, except in the absence of organic matter. This difference may be owing to the absence of marshy land through which the Inglewood water could be drained, comparable to the marsh which intervenes between the St. Anthony Falls springs and the supposed source of their water.

The following analysis was made by Dr. William A. Noyes in 1883:

		Grains per gallon.
Calcium carbonate,		9.794
Magnesium carbonate,		4.693
Lithium carbonate,	trace	
Calcium sulphate,		.117
Sodium sulphate,		.485
Potassium sulphate,		.169
Sodium chloride,		.076
Calcium nitrite,	trace	
Iron and alumina,		.012
Calcium phosphate,	trace	
Silica,		1.220
Total grains per gallon,		16.56

The following analysis was made by Mr. C. F. Sidener, at the university laboratory, Jan. 21, 1886. This is from the "New Inglewood spring."

		Grains per gallon.
Calcium carbonate,		9.6594
Magnesium carbonate,		5.3923
Iron carbonate,		.0338
Calcium sulphate,		.3768
Sodium sulphate,		.2642
Potassium sulphate,		.2360
Sodium chloride,		.0504
Nitrites,	slight traces	
Nitrates,	slight traces	
Phosphates,	traces	
Alumina,		.0688
Silica,		1.0417
Total grains per gallon,		17.1234

Tests for organic substances in this water.

	Parts per million.
Free ammonia,	.01
Albuminoid ammonia,	.048
Permanganate oxygen consumed,	.018

Test of hardness — $18\frac{1}{2}$ degrees.

Temperature of water at spring — 46 degrees, Fahrenheit.

The water of the Inglewood springs is used for common drinking quite extensively in Minneapolis. By the proprietors it is delivered throughout the city.

The Glenwood springs are situated near the Inglewood springs, and have the same origin, chemical character and reputation. They are owned by Mr. W. H. Fruin. They are well known as a local resort in summer.

Prof. James A. Dodge, of the university, gives the following results of analysis of the Glenwood spring water, February, 1885:

		Grains per gallon.
Calcium carbonate,		10.191
Magnesium carbonate,		4.705
Sodium carbonate,		.257
Potassium carbonate,		.204
Iron carbonate,		.041
Sodium sulphate,		.612
Lithium salts,	slight traces	
Phosphates,	slight traces	
Nitrates,	very slight traces	
Sodium chloride,		.105
Alumina,		.058
Silica,		1.609
Total grains per gallon,		17.782

Organic substances found in the water.

	Parts per million.
Free ammonia,	.005
Albuminoid ammonia,	None.
Permanganate test,	Very slight indication.

The Great Medicine spring, an old resort of the Indians, is situated a few miles west of Minneapolis. It is chalybeate, as shown by its taste, and by the irony coating formed by the water on the surface over which it runs, but its exact chemical qualities are not known.

At a short distance below the university copious lime-water issues from the bluffs, depositing a calcareous tufa, which in favorable circumstances has become several feet thick. When the spattering water falls on moss, which often grows in such damp spots, it covers the moss with a film of carbonate of lime, which, by gradually increasing, imprisons the moss, killing it, but takes its form, and even its name, the moss itself gradually oxidizing and passing off in the air as grass decays on the prairie. The deposit, loose and spongy, is then known as *petrified moss*.

Mr. W. W. Norton has a chalybeate spring, S. W. ¼ sec. 11, T. 28, R. 24, on the line of extension of Park avenue, south from Minneapolis. This seems to be produced by drainage from a swamp, and if its chemical qualities were known with exactness it is probable that the water would be found to contain organic impurities similar to the water of the St. Anthony Falls springs. Where this swamp drains southward, the water deposits organic impurities of a greenish color, and also some bog iron ore. This is revealed by recent excavations for the grade of Park avenue.

The water of lake Minnetonka, which is produced by surface drainage from the gray till, has the following mineral impurities, according to analysis by Dr. William A. Noyes. This sample was taken about midway between Excelsior and Morse island, May 2, 1883, by Dr. Noyes, the analysis being performed immediately.

		Grains per gallon.
Calcium carbonate,		4.088
Magnesium carbonate,		1.618
Lithium carbonate,	traces	
Potassium carbonate,		.263
Sodium carbonate,		.082
Sodium sulphate,	traces	
Sodium phosphate,	traces	
Borax,	traces	
Sodium chloride,		.076
Potassium nitrate,	traces	
Iron,	traces	
Silica,		2.80
Total grains per gallon,		6.407

"The amount of dissolved salts is, on the whole, rather small. The water is remarkable for the almost total absence of sulphates. It was also found to be very pure organically, the permanganate test of Forschammer and Tidy indicating very little organic matter."

The water of the Mississippi at Minneapolis was examined chemically with a view to determine what difference might show itself in the water taken from above and below the city.* The sample from above the city was from a point on the west bank about half a mile above the Plymouth avenue bridge, beyond all apparent considerable sources of contamination, and that from below the city was taken, also on the west bank, below the brewery, at the small grove near the old fair grounds, beyond all probable inflow of impurities from the city. According to Prof. J. A. Dodge these samples gave the following results on analysis:

	Grains per gallon.	
	Above the city.	Below the city.
Silica,	.78256	.97090
Calcium carbonate,	6.39532	6.13722
Magnesium carbonate,	3.15307	2.42827
Iron carbonate,	.05504	.15560
Sodium chloride	.16352	.18408
Potash,	.10162	.15826

*See the tenth annual report, p. 206.

Soda,	.17462	.15126
Sulphuric acid,	.16445	.17462
Nitric acid,	traces	traces, more than in No. 1.
Total mineral matter,	10.99020	10.36021
Organic matter,	1.40228	1.96219
Total mineral and organic matter,	12.39248	12.32240
	Parts per million.	Parts per million.
Free ammonia,	.0175	.0266
Albumiuoid ammonia,	.0625	.1550

Of these results Prof. Dodge remarks: "I would call attention to the following points: *First*, the amount of matter, mineral and organic together, differs but little in the residues from the evaporation of the two waters; but the amount of organic matter in the water from below the city is appreciably larger than in the water from above. On the other hand the amount of mineral matter is larger in the water from above. This latter result was to me wholly unexpected, but I am certain of its correctness. The water of the river below contains a little less carbonate of lime and magnesia than the water above. The difference, however, is wholly immaterial in a practical point of view, and may be accounted for by the influx of several creeks which bring in softer water than the river;* also by the consideration that what lime finds its way into the river from factories and from mason's use may serve to precipitate a small part of the carbonate of lime and magnesia that are in the river. *Second*, the difference in the amounts of organic matter in the two samples is quite material in sanitary respects. The results of the determination of free ammonia and albuminoid ammonia are such as to place the water from above the city under the head of good drinking water, while that from below would be excluded from that class. It is to be observed that the water from below shows somewhat more of all ingredients except lime and magnesia. In the case of nitrates a quantitative determination could not be made. Qualitative tests showed somewhat more in the water below." The water used for domestic purposes, distributed by the city water-works, is taken from near the centre of the river, about midway between the two points chosen above, but above the falls of St. Anthony. The plan of the city sewerage carries nearly all the sewage of the city into the river below the falls.

Glacial marks. The marks of the ancient glaciers have been seen at several points about the falls of St. Anthony.

On the west side of the river, at Banks Arenson's quarry, a short distance below the falls, the direction of these marks is N. N. W. and S. S. E. They are overlain by a stony till of an olive-gray color. On Hennepin island, above the paper-mill, they are S. 22° E; on Nicollet island, S. 5° E. (Upham). On the west side of the river, nearly opposite the university, "a space is exposed on the surface of the limerock about 100 feet by 40 feet, which is grooved and scored in parallel lines. The principal series of striæ run S. 15° E. There is a second series which are less numerous and run S. 28° E. (Herrick). The rock-surface exposed by the excavation for the city market, corner Washington avenue and Second street, was found to be polished and promiscuously scratched, with no prevalent direction discernible.

* On the other hand the creeks that enter the Mississippi between the two points chosen seem to carry water harder than that of the Mississippi.—N. H. W.

On Central avenue, in East Minneapolis, corner of Second street, under a red till, which lay compactly on the rock surface, the marking was not distinctly defined as to direction, but showed a congeries of confused markings. In one place, a deeper grooving, though worn and somewhat obscured, had a direction S. 15° E.

THE RECESSION OF THE FALLS OF ST. ANTHONY.

From the falls of St. Anthony to Fort Snelling the gorge between the rock-bluffs is somewhat less than a quarter of a mile in width, and the rock has a freshly-broken appearance, the large fragments thrown down by the action of the water on the easily crumbled sandrock, as the falls have receded, still existing in the talus along the bluffs. Throughout this distance (about eight miles) the strata are horizontal, the thickness of the drift sheet overlying them nearly uniform, and all other conditions, so far as they can be seen, that would affect the rate of recession, seem to have exerted an unvarying influence. The inference is inevitable that the rate of recession has been practically uniform between the two points named. There is an aspect of age, and long weathering, presented by the rock in the bluffs of the Mississippi below Fort Snelling. It has a deeply changed color, a light-yellow, oxydized exterior, which marks all old bluffs.* The blue color is founed at greater depth from the surface than it is in the rock of the bluffs above Fort Snelling. This stained condition also pervades the limerock at the mouth of Bassett's creek and at the quarries in the ancient river bluffs near the mouth of Shingle creek, on both sides of the river. Another notable difference between the bluffs above Fort Snelling and those below consists in the absence of caves, and subterranean streams entering the river, above Fort Snelling. Although the Trenton limestone exists in full force about St. Paul, in the bluffs east and north of the city, yet it had been cut through by some means prior to the drift so as to allow the entrance and exit of streams of water at levels below its horizon, through the sandstone. None such are found above Fort Snelling. The surface drainage is shed by the limestone, and is precipitated over the brink of the gorge forming several beautiful cascades. When such streams enter the river below Fort Snelling they either enter some subterranean passage and appear at the mouths of caverns in the sandstone, or as springs

* Compare the chapter on building-stones in Minnesota, vol. i, p. 190, for a full account of the changes of color of which a rock is susceptible under long exposure to the natural elements.

in the drift along the talus, or they find an ancient ravine down which they plunge, by a series of rapids over boulders, to the river level, rarely striking either the limerock or the underlying sandrock. Again, the rock-bluffs at St. Paul, and everywhere below Fort Snelling, are buried under the drift-sheet. Their angles are sometimes seen jutting out from some wind-beaten corner, but nearly everywhere they are smoothed over by a mantle of drift and loam. Even the immediate river-bank, where the limerock should be intact, shows it has been extensively disrupted and its debris, often coarse and water-worn, in pieces from four to ten feet long, is mixed with the coarse boulders and gravel of the drift, at the hight of fifty to seventy-five feet above the water level, the heterogeneous mass lying on the worn upper surface of the St. Peter sandstone. But above Fort Snelling the upper edge of the limerock is intact all the way to the falls, and shows a fresh-cut section. It is surmounted by a continuous sheet of drift which rises from the water level in one bluff coincident with the rock-cut. Its individual strata show that they were cut by the recession of the falls, in the same manner as the strata of the rock. They do not conform in their undulations to the outline of the rock, as if the gorge were present when they were formed, as at St. Paul. There is no spreading of loam over these cut edges, except such as has fallen down from above at the time of their removal, or subsequent to it. At Fort Snelling the direction of the Mississippi changes abruptly at a right angle. The change is caused by its entering the wide gorge which runs in that direction. This gorge is that in which the Minnesota runs, and is out of proportion with the amount of water which it carries. This valley continues in the same direction, and with the same width, beyond the confluence of the Mississippi, but takes the name of the latter stream. At one mile below the mouth of the Minnesota it is a mile and a half wide.*

These features of greater age, pertaining to the bluffs of the Mississippi below Fort Snelling, are seen in the old rock-bluffs of the river above the mouth of Bassett's creek as far as to Shingle creek. The rock there is deeply changed in color, and is hid by the drift, and the bluffs, as left by the more ancient river, are far apart, the old gorge being three or four times as wide as that between the falls and Fort Snelling. These rock-bluffs, consisting of the

* General G. K. Warren. *Bridging the Mississippi.* p. 922.

same limestone as that which at the falls is below the water, here rise from thirty to forty feet above the river, and are buried under loam, or under drift and loam. This part of the old valley continues southwardly, by way of Bassett's creek (below its last turn), across the western suburbs of Minneapolis, through the valley occupied by lakes Calhoun and Harriet, and joins the Minnesota at some point above Fort Snelling, the precise locality being hid by a subsequent deposit of drift. It was cut down into the St. Peter sandstone over 100 feet at least, as shown by the well at the Sumner schoolhouse, and about 275 feet as shown by the deep well at the Lakewood cemetery. This would show that probably the ancient valley of the Minnesota, where it passes Fort Snelling, and all the way through Ramsey county, and below, has been filled more than two hundred feet by drift that originated since the excavation of the gorge. This supposition is borne out by all borings that have been made between the rock-bluffs at lower points, as at West St. Paul, and at Lake City. Such excavation is not found in the river gorge between Fort Snelling and the falls of St. Anthony; but, below the water, are found, first, some large fragments of limestone, and some boulders of foreign origin, the whole being generally less than twenty-five feet in thickness, and below that the undisturbed St. Peter sandrock is found, suitable for the foundations of piers for bridges.

These facts warrant the conclusion that that part of the Mississippi gorge above Fort Snelling has been excavated by the recession of the falls since the last general drift-movement, and that prior to that event there was a gorge which passed from the present channel of the Mississippi at the mouth of Bassett's creek, southward to the great gorge of the Minnesota at some place above Fort Snelling. It is probable that this gorge was then occupied by waters that drained from the northern part of the state, and had existed through many ages, dating back to pre-Cretaceous times. It seems to have been filled first by a blue till, or partly filled, and to have remained free for the passage of the Mississippi during the on-coming of the glacial epoch, till the advent of the ice of the last glacial epoch when morainic accumulations so choked it that the water of the river was driven out and compelled to seek another passage to the Minnesota. When this last event took place the falls of St. Anthony probably began at Fort Snelling, the water being precipitated over the rock-bluff of the pre-existing old gorge unless the whole valley was too deeply buried under water. Whether this was at the beginning, or at the acme of cold, or at the time of recession of the ice, is a question which may well be considered, but at this time the only point that is claimed is that it was not earlier than the beginning of the last glacial epoch, and was prcbably near the acme of cold.

Assuming that the rate of recession from Fort Snelling to the point at which the falls were at the time of the first general setlement of the region in 1856 was uniform, it remains only to find a datum for establishing that rate, to be enabled to compute the time that has been required for the whole distance, and hence to fix an approximate date to the last glacial epoch.* The rate has been much greater since the construction of dams and mills, diverting the water

* In a discussion which followed the reading of a paper of the writer on this subject at the November meeting of the *Geological Society of London*, 1878, Prof. W. Boyd Dawkins objected to the conclusions arrived at, because "the calculation was based on the assumption that the rainfall had been constant in the district, and that the quantity of water descending over the falls had been constant," stating that he deemed *it the duty of geologists to point out the impossibility of correlating historical and geological time.*

The variations in rainfall to which he appealed are those "known to have taken place in Europe in consequence of the destruction of forests, etc.". Only mentioning the fact that no such forests are known to have been destroyed in this district since the last glacial epoch, but that the region drained by the upper Mississippi is still covered by the "forest primeval," it might be said truthfully that all the known variation that can be proven in Europe or in America in the volume of any river, from this cause, would not introduce an element worthy of serious consideration in the discussion.

Prof. Hughes thought, (1) "It was doubtful whether the exact amount of former extension of the rock could be estimated from such observations as those recorded by early travelers; (2) the period down to which glacial conditions prevailed did not appear, from what he had heard of the paper, to be very clearly made out; (3) if these points could be proved, they would involve such changes, from the climatal conditions that would allow the interception of the streams of neighboring valleys by glacier ice, to the present state of things, when the existence of saw-mills implied ancient forests being destroyed, that uniformity in the rate of waste certainly could not be assumed."

In regard to the first objection of Prof. Hughes, it is only necessary to say that it seems very certain that the position of the falls can be established with remarkable accuracy by the descriptions and illustrations that early travelers have given. This part of the evidence is absolutely undeniable, so far as the testimony of all the travelers quoted back to and including Carver, is concerned, and is questionable only as to that of Hennepin. In regard to Hennepin, if there be any error, it is only possible that the island he saw was further down the river, and has since been destroyed. This would increase the rate of recession between Hennepin and Carver, and would tend to shorten the time obtained for the recession from Fort Snelling, and would throw upon us the necessity of accounting for a smaller proportionate recession since Carver than the facts will warrant.

The second point made by Prof. Hughes is no objection at all, since, if the *period down to which glacial conditions prevailed* had been clearly made out, there would have been no need of the investigation at all, or at least there would have been no need of continuing the investigation to its conclusion, since *it is the object and burden of the whole paper to ascertain*, by the recession of the falls, as nearly as possible the period down to which glacial conditions prevailed. It is fair to suppose that this point of Prof. Hughes is not correctly stated in the printed report of his remarks, and that he actually called attention to what he thought absence of proof as to the limit, geographical limit, of glacial conditions at this point in the Mississippi valley. With that understanding of his objection, it has considerable weight, and it must be admitted that the evidence in the paper referred to, on this point, is not convincing. Since this calculation was first made, however, much new light has been added to the evidence on this point of the argument, and the corroboration of Mr. Warren Upham, an assistant on the survey, and of Prof. T. C. Chamberlin, of the United States Geological Survey, is ample to satisfy all that the claim of the writer, as set forth in the fifth report of progress of the Minnesota survey, was based on correct observation and was valid. On this point the reader may consult the ninth annual report of the survey, plate vi, where the course of the terminal moraines of the second glacial epoch in Minnesota and Iowa, is shown; also the third annual report of the United States Geological Survey, plate xxxv.

The third point of Prof. Hughes has more weight with one who is unacquainted with the nature of the country drained by the Mississippi, above the falls of St. Anthony, than with one who is familiar with it. If the region were mountainous, if it were reasonable to presume that local glaciers projected their ice-currents across valleys hidden between ridges of rocky barriers, if tributary streams could thus have been shut up, filling those valleys with temporary lakes, compelling them to find discharge by some other route to the ocean, there might have been some irregularity in the volume of water discharged over the rock at the falls of St. Anthony. But, providing these things all conspired to produce such variation, they could only have operated *while the glacial conditions were in full force*, and during the ice-period itself, and would have had but little effect on the period of time the length of which it is intended here to measure. But the region of the upper Mississippi is not mountainous. It is a broad plateau, with gentle, broad undulations. From its source to the brink of the falls of St. Anthony the Mississippi descends 775 feet, the direct distance being 180 miles. When the ice of the glacial epoch existed in the region it must have covered it evenly, or nearly so, and the water-courses that flowed from it, or that resulted from its final dissolution, must have maintained a uniformity of volume and a constancy in direction and position nearly equal to what is seen at the present time. After the ice had withdrawn or concentrating it at points, and particularly since it became customary to float logs for lumber down the Mississippi and allow them to pass over the falls, for the use of saw-mills further down the river. Since 1871, however, the recession has been stopped entirely, by means of artificial structures which have prevented the destruction of the sandrock, and by the substitution of a sluice-way for the passage of sawlogs. The rate of recession since the permanent occupancy of the region is valueless for this purpose. Fortunately there are islands and other land-marks still preserved about the falls by which the position of the brink of the falls at certain dates during the last two hundred years can be fixed with a degree of accuracy sufficient for this calculation.

The first authority which it is necessary to refer to is that which fixes the position of the falls in 1856. There are many citizens of Minneapolis living who can describe the appearance and position of the falls at that date. Of these the following have been consulted, viz.: Mr. Richard Chute, Mr. S. W. Farnham, Judge N. H. Hemiup and Dr. A. E. Johnson; and they concur in the following description.

In 1856 the falls were divided by the island which is now known as Hennepin island in the same manner as they are at present, but on the west side of the island, were, in general terms, abreast of the saw-mill of Messrs. Farnham and Lovejoy. They had a bend upward in the centre of the channel, and a sweep downward near the west shore, the two ends being nearly opposite each other. The downward sweep of the brink, on the east side of this

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from the state the volume of the Mississippi above the falls must have attained very soon nearly its present dimension; below Fort Snelling, where the Minnesota joins it, the volume of water remained for an unknown length of time, still swollen by the drainage from lake Agassiz through the gap between Big Stone lake and lake Traverse, in the western part of the state. On the other side of the state, if the lake Superior glacier obstructed the outlet of that basin for a period of time after the ice had retired from Minnesota (as is probable), it found discharge to the Mississippi by way of the valley of the St. Croix, and joined "the great river" about thirty miles below the falls of St. Anthony, or by way of the Des Plaines and Illinois rivers.

It would be well also to note that the existence of saw-mills at the falls of St. Anthony hardly implies that ancient forests are being destroyed. It only implies that a few pine trees are felled annually from the forests that cover the northern part of the state at the present time, and their loss produces no effect upon the average precipitation. The exhaustion of the pine suitable for lumber in the Northwest does not imply the destruction of the forests of the Northwest.

Mr. J. C. Southall, in *The Epoch of the Mammoth*, p. 373, while accepting the conclusions of this discussion, as published in the fifth annual report, mentions some circumstances which he thinks would operate to retard the recession of the falls since they entered upon Hennepin island. The first is the division of the channel by the islands, which he thinks would weaken the power of erosion by the river. On the contrary it would seem that the very opposite result would be produced—unless the width of the river at the brink be correspondingly increased. An island introduced into the brink of a water-fall would concentrate the water in narrower chutes and would cause a greater momentum against the rock below. It should also be remembered that whatever the effect of islands in the brink since Hennepin's discovery, there is every probability that other islands divided the brink before Hennepin saw the falls. Pike says there were twelve islands in the river between the falls and Fort Snelling in 1805. Probably each one represents the debris of an island which once divided the falls. The other circumstance mentioned by Mr. Southall is that the width of the river between Spirit island and the falls is twice as great as from Spirit island to Fort Snelling. But the width of the river has nothing to do with the discussion—and especially that part of it which is below Spirit island. It is wide or narrow according to the accidental posé of the coarse debris left by the recession of the falls. It is broader and shallow just below the falls because it has to gather itself together from the two channels. It is broader above the falls because since 1856 there has been a dam above the falls. It is narrow below Spirit island because it is rapid and choked by the talus from the bluffs. But the width of the gorge, which has been cut by it, is substantially uniform from Fort Snelling to Minneapolis.

channel, met the shore of Hennepin island about one hundred feet below the lowest point of the flat undisturbed portion of the limerock on which Farnham and Lovejoy's mill-dam is erected; the mill itself having been erected originally in a little notch or jog in the falls, partly on the limerock, and partly below the falls, close on the shore of the island. The falls in the channel on the east side of Hennepin island, having been more protected, have not receded any perceptible amount since 1856. There were two low small islands below the falls, in the west channel, one near Hennepin island, and one near the west shore. Spirit island was considerably larger than now and was frequented by eagles.

Dimensions of the gorge below the falls of St. Anthony.

At what bridge.	Length of bridge; feet.	Between limestone bluffs; feet.	Roadway above the sea; feet.	Roadway above low water; feet.	Top of the limestone above the sea;* feet.	Top of the limestone above low water; feet.	Authority.
St. Paul, Minneapolis and Manitoba railway,	diagonal	1700†	807	60	784	37	C. C. Smith.
Tenth avenue South,	1140	978	807	68	782	43	F. W. Capellen.
St. Paul and Northern Pacific railway,	1582	885	815	92	773	55	F. W. Capellen.
Washington avenue,	1080	885	812	91.5	776	55.5	F. W. Capellen.
Franklin avenue,	1000	950	812	99.78	788	76	F. W. Capellen.
Chicago, Milwaukee and St. Paul railway, -	1144	750	845	134	790	79	M. D. Rhame.
Lake street,	1200	1150	815	109	783	77 (?)	F. W. Capellen.
Fort Snelling,	1018	1000	807	116.5	791	100.5	H. E. Horton.

* This is meant to be the regular building-stone layers, which are 15 feet thick.
† This is the width at the upper end of the bridge, according to M. D. Rhame; at the lower end it is the same as that given for the Tenth avenue bridge. The city datum of Minneapolis is 712 feet above the sea.

The total width of the river, including Hennepin island, was 1700 feet at the falls. Since 1856 the falls in the west channel have receded about 500 feet, hastened by the causes mentioned. The width of the gorge at the bridge at Tenth avenue South, according to city bridge engineer F. W. Capellen, is 978 feet. At the bridge of the St. Paul and Northern Pacific railway, according to chief engineer J. W. Kendrick, it is 885 feet. At the Washington avenue bridge Mr. Capellen gives it 885 feet. At the Franklin avenue bridge Mr. Capellen gives it 950 feet. At the Lake street bridge, by the same

PLATE M.

RICHARDT'S ST. ANTHONY FALLS—1857.

authority, it is 1150 feet. At the bridge of the Chicago, Milwaukee and St. Paul railway it is 750 feet according to the profiles of the resident engineer, M. D. Rhame; the highway bridge, at Fort Snelling, across the same gorge, extending from one rock-bluff to the other is 1018 feet long, according to Mr. Horace Horton, under whose superintendence it was built.

Richardt's St. Anthony Falls—1857.

In 1857 an artist whose name appears on the canvas as Fred. Richardt, sketched and painted a large representation of the falls of St. Anthony. This is now owned by Hon. Richard Chute, of Minneapolis. It is dated 1858, but the sketch was made, according to Dr. S. H. Chute, a year before. This is reproduced on a small scale, by heliotype from the painting, on plate M. This shows Hennepin island dividing the falls into unequal parts, the larger being on the west side; Cataract island, a low mound of sandstone in the midst of the river,* nearly hid by fallen blocks of limerock and by vegetation, is below the falls, a little to the west of Hennepin island; Spirit island is further west, and further below the falls, but consists of rock in its undisturbed position; a little above Spirit island, and further west still, is a small island with a few trees, consisting apparently only of lodged debris. The view is taken from the west shore, and shows the first houses of the village of St. Anthony. In the distance the river is spanned by the first suspension bridge. The artistic construction and the perspective of this painting is correct to nature.

J. W. Bond's description of the Falls in 1853.

It is fortunate that so full a description of the falls of St. Anthony as they existed about the time of the erection of saw-mills on their banks, has been preserved. This is found in *Minnesota and its Resources,* by J. Wesley Bond.

Opposite the village (St. Anthony Falls) three islands, lying nearly in a straight line, one above the other, divide the river into two parts—the largest body of water flowing on the right hand of the islands. The upper island is small [Boom island.—N. H. W.] containing less than ten acres of land, and is still uncultivated, though the trees with which it was but a short time since densely covered are fast disappearing, and it will soon be brought under tribute to the husbandman.

The second island is some eight or ten rods below, and contains about forty acres [Nicollet island.—N. H. W.] It is a beautiful spot of ground covered thickly with a great variety of thrifty timber, among which the sugar maple is conspicuous. The banks are high, bold and rocky on the upper end, gradually descending at the lower almost to the water's edge. Near the middle of the island a small bluff rises some ten or fifteen feet high, with a slope as nicely and beautifully turned as if it had been the work

* Dr. S. H. Chute is authority for the statement that undisturbed sandrock forms the basis of Cataract island.

of art. It forms a semi-circular curve at the lower end, gradually widening toward the upper, making one of the most charming building-sites that can be imagined. Near the lower end of this island commence the rapids in the main stream, the water foaming, bounding, and dashing over the rocks, which lie scattered across the bed of the stream as far as the falls.

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The third island [Hennepin island.—N. H. W.] lies immediately below, so near the last mentioned that they were formerly connected by a slight bridge. It contains, on a rough estimate, some fifteen acres, and is not yet surveyed. A small house has been erected upon it by the mill company as a pre-emption claim. On each side of this island are the falls of St. Anthony. Below the falls are two small islands near the right shore. The falls of the main channel are several rods above those on this side, the greater volume of water having worn away the soft crumbling rock much faster. The recedence of the falls on both sides is so rapid as to be almost yearly perceptible; making the suppositions of some geologists highly plausible that originally they were as low as Fort Snelling. During the high water of 1850 huge masses of rocks were torn from the islands* washed by the falls, and carried a considerable distance down the river; large blocks of sand and limestone were detached from the ledge of rock over which the water is precipitated, and altogether, the falls underwent a greater change than had been observed for many years.

Capt. S. Eastman's St. Anthony Falls.

Another view, showing the falls as they were about the same date, was drawn by Capt. S. Eastman, U. S. A., when stationed at Fort Snelling. This was published by Lippincott, Grambo & Co., Philadelphia, in 1853, and is plate 28, of Schoolcraft's *Indian tribes*. It was also inserted as one of the steel plate page illustrations of Mr. E. D. Neill's *History of Minnesota*, quarto edition, in 1858. This view is shown by plate N. On the west side this shows some buildings just below the falls on the river bank, some of them being within the gorge. Spirit island is shown in the midst of the river, the summit covered with trees, but the distinction between the strata of limerock and sandrock, so marked in nature on the island and along the bluffs of the gorge, is entirely ignored. Hennepin island is projected, by its fallen debris, some distance below the base of the falls. Cataract island is conspicuous. The east channel is represented as about one-third the whole width of the falls, not including Hennepin island. Nicollet island is shown plainly, separated by a narrow passage from Hennepin island. Numerous blocks of detached rock are seen at the base of the waterfall, and some are also lodged on the very brink, or are midway in the descent, lying on others.

This plan of the falls gives an impression of too great width in comparison with their hight; and Spirit island is much too large for its perspective position.

Hesler's daguerrotypes of the Falls in 1851.

In 1851 Mr. Alexander Hesler made daguerrotypes of the falls. Three of

* See Hesler's daguerreotypes made in 1851.

Drawn by Captⁿ S. Eastman, U.S.A. Engᵈ by J. C. McRae

EASTMAN'S FALLS OF ST. ANTHONY.—1853.

WEST CHANNEL OF THE FALLS OF ST. ANTHONY IN 1851.
From daguerreotype by ALEX. HESLER, of Chicago.

Spirit I. Nicollet I. Cataract I. Hennepin I.

The east channel is not visible.

VIEW FROM HENNEPIN I. WESTWARD—1851.
From daguerreotype by ALEX. HESLER, of Chicago.

GLIMPSE OVER THE EAST CHANNEL—1851.
From daguerreotype by ALEX. HESLER, of Chicago.
Buildings on Main Street.

HENNEPIN ISLAND, LOOKING OVER THE EAST CHANNEL.
Enlarged by C. A. Zimmerman from a daguerreotype taken in 1851 by J. E. Whitney.

EAST SHORE—SHOWING ST. ANTHONY.

Enlarged by C. A. Zimmerman from a daguerreotype taken in 1851 by J. E. Whitney.

THE FALLS OF ST. ANTHONY.

these are reproduced in plates O. P. and Q. The first is a view of the falls in the west channel showing Spirit and Cataract islands. Hennepin island here overlaps Nicollet island so that the two can hardly be distinguished. The apparent hight of the falls is reduced by this method, while the size of the river below the falls is made to appear unduly magnified. The second of these daguerreotypes, plate P., is taken from the west side of Hennepin island, and illustrates the zigzag course of the rock-brink described by Keating, as well as the method and the agents by which the recession is accomplished. The drift-wood here lodged is that which naturally comes down the river. Plate Q. shows a portion of the east channel, from Hennepin island, including some of the buildings of St. Anthony Falls village. J. E. Whitney made daguerreotypes of the falls in 1851. See plates R. and S.

Lewis' view of the Falls of St. Anthony.

In 1848 Mr. H. Lewis, an artist of St. Louis, visited the falls of St. Anthony. He made a sketch which was published at Düsseldorf. It was lithographed by Just. Arnz and Co. It was exhibited as one of a series of panoramic views illustrating the valley of the Mississippi, by a traveling lecturer, and may be seen in the German work entitled *Das illustrirte Mississippi Thal.** This shows not a building about the falls. Hennepin island is in the midst of the falls a little to the east of the middle, and Spirit island just below the falls a little to the west of the middle. Numerous dislodged blocks

* The full title of this work is Das illustrirte Mississippi Thal, dargestellt in 80 nach der Natur aufgenomen Ansichten, vom Wasserfalle zu St. Anthony an bis zum Golf von Mexico.(eine Entfernung von ungefähr 2300 Englishen Meilen), von H. Lewis, Landschafts-maler aus St. Louis in Missouri. Nebst einer historischen und geographischen Beschreibung der den Fluss begränzenden Länder, mit besonderer Rucksicht auf die verschiedenen den obern Mississippi bewohnenden Indianerstämme (deutsch und english), von George B. Douglass, ausgeführt in lithographischen Institut von Arnz & Comp. in Düsseldorf.

Other colored lithographs in this volume are as follows, each occupying a page: *Fort Snelling*, taken from some point near Mendota, perhaps Pilot Knob. This view shows Pike island, the trading post (?) near the mouth of the Minnesota, now the house occupied by the ferryman on the south side of the Minnesota, a large encampment of tepees about where "Cold Spring" used to be, and a house on the bottom land of the Mississippi above the mouth of the Minnesota, about where the Fort Snelling depot now is; besides the fort itself, and other buildings on the bluff. *The Rolling Prairies* [in the] *The Valley of St. Peter's*. This must certainly have been taken from near Fort Snelling, and it is a fine representation of the broad valley there visible, with its serpentine lines of trees fringing the immediate channel of the river. In the foreground are two gaudily-robed Indians seated on some stones near a large fallen tree. *The Little Falls.* This is Minnehaha falls. There is a break in the brink caused by a projecting rocky knob. The limestone is represented distinct from the sandstone. The same fault appears here as in the view of the falls of St. Anthony, viz.: the banks recede at once, particularly the right bank, to the level of the water below the falls. *St. Paul's, im Minnesotah Territorium.* This is a view from down the river. It represents four buildings on the levee, one being the old stone store, still standing, with a front porch covering the lower story in the manner of trading houses and saloons. The other three are below this. There are two roads going up the hill from the boat landing, one about due north, and the other northwest. Another passes up from the lowest of the four buildings. On the bluff are visible ten buildings, with some scattering trees, and more trees in the background. The three buildings on the levee, besides the store, are apparently made of logs. Those on the bluff are apparently of boards standing upright. There is one island in the river. The artist here has ignored the true geology and only represents a short perpendicular rocky bluff, extending in front of the buildings on the bluff—being probably at the foot of Wabasha street. A reflective Indian smokes his pipe in the foreground sitting on a fallen tree near the water and watching a boat-load of people in the centre of the stream. Seven other boats, or canoes, are seen at the levee, with their prows loosely moored on the beach. *Klein Robendorf.* This is Little Crow's village (or Kaposia, on the west side of the Mississippi), looking down stream. It represents from twelve to fifteen cabins on the low river-bank, and several scaffold-graves on the bluffs adjoining. There is one house, with windows and chimney, at the lower end of the village. The cabins are low, and have a single broad entrance at the gable end. They are apparently made of timbers or boards standing upright. The bluffs, with of the limestone are seen below the falls, causing rapids, and some are adhering still to the brink and serving to catch floating drift-wood. Nicollet island is represented immediately above Hennepin island. A scarlet-robed Indian stands solitary on the right bank above the falls with his quiver of arrows across his back, gazing up stream. A fringe of trees skirts along the banks of the river, especially on the west side. Spirit island is represented high and perpendicular with rock walls, the line of separation between the lime-rock and sandrock being particularly distinct. The little low island, now known as Cataract island, is seen below the falls a little to the left of the lower end of Hennepin island. These islands are all covered with trees in which the contrasted forms and foliage strongly mark both coniferous and deciduous species, some of the former overhanging the bluffs like red cedars. The country beyond, on either side, is represented as mainly prairie. There is an imperfection in the execution of this picture by the artist, in that the point where the Indian stands appears to be no higher than the river which runs beside him, but actually the bluff all along there is from 75 to 100 feet higher than the river. This view is represented by plate T.

A. F. Lœmans' Falls of St. Anthony.

In 1877 Mr. A. F. Lœmans, an artist then resident at Minneapolis, painted on canvas an ideal reproduction of the falls of St. Anthony as they were in 1842. This painting was based on the verbal descriptions of early visitors, adjusted with the known present position of the islands and banks of the river. Aside from the addition of some ideal foliage, in excess of nature, and the

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scattering timber, are cut by ravines, and rise apparently 150 feet above the village flat. Numerous canoes are in the river, moored along the shore. *Rothe felsen prairie.* This locality, which is now known for the annual Methodist camp-meeting held there, the site of the first stated Christian worship in the state, is represented in a view from the south, apparently from an island in the river. In the foreground are nine Indians, gaily dressed, with several children and a dog, their canoes apparently having been just unloaded. In the distance at the right is a low prairie-expanse bordered by the river on the left and the high outer bluffs of the river on the right. In the centre of this prairie are four cabins and a pile of lumber. There is an indistinct group of persons gathered about a spot in the prairie, probably intended to represent Indians paying homage to the "red rock" of the locality. Two islands appear in the river opposite the prairie. In the distance the Mississippi recedes slowly and disappears by turning to the left. The book says, as translated: "Below the village, in the distance, can be seen two islands. That on the left is the Maiden's isle. There the Indians celebrate the maiden festival, in which no one who is not qualified for it can take part. Tradition relates that a maiden, on complaint of a rejected lover, was debarred from this festival, and hung herself on this island." *The mouth of the river St. Croix.* This shows a raft of lumber, a steamboat and a large, apparently rocky, island, in the river. There is a house surrounded with palisades on the right, and a small house in the timber on the left. *Red Wing's village.* This shows Barn and Sorin bluffs, and the village some distance above them. At the base of the bluffs, and about between them, near the river, separated from Red Wing's village by a little stream that enters the Mississippi, is apparently an English house, at least a European house, or a house and barn. Barn bluff shows rock strata near the top, but Sorin bluff is a gradual slope from top to bottom composed of drift and talus matter. *The Indian Cemetery, Lake Pepin.* A very imperfect representation. *The Maiden rock, der Werona felsen.* Shows the bluff of Maiden rock from the north. A single canoe is seen in the river, and the opposite bluffs in the distance. *Medizinfluschendorf, Mouth of the Chippewa, Wisconsin;* and several others probably located in Minnesota, representing Indian life, but having nothing certainly placing them in this state. The only known copy extant of this rare book is owned by Rev. C. J. Knauf, of Adrian, Minn. It is through his courtesy and that of Rev. James McGolrick that it was possible to obtain the foregoing description.

PLATE U.

LŒMANS' REPRODUCTION OF 1842.

P. S. FORKART-HALL.

hightening of the falls in proportion to their width, this reproduction is doubtless about correct. It shows Spirit island in the river below the west channel. This island is represented as high, and with perpendicular rocky sides, having a covering of deciduous trees. To the east of this, near the foot of Hennepin island, is a low, small island, evidently composed of rocky debris from the falling down of the limerock stratum. This contains both deciduous and evergreen trees. Hennepin island divides the falls into two unequal parts. It is prolonged below the falls as a high platform, and still further as a low island composed of debris. Both parts have a covering of trees. Hennepin island, from the point of view taken, projects westward so as to overlap Nicollet island, and the channel between them cannot be seen. Hence there is no distinction, except in a slight difference in the distinctness of the foliage, between Hennepin and Nicollet islands. Below the falls, at the west side of the west channel, are represented some trees, some of them being coniferous; growing on some debris well up toward the foot of the falls. This line of debris, which runs now some hundreds of feet further up on account of the recession since 1848, exists to this day, but its position and amount have been modified by artificial means. An Indian camping and cooking scene on the bluff below the falls enlivens the foreground at the left. This view of the falls is represented in plate U.

G. W. Featherstonhaugh's description in 1835.

In 1835 Mr. G. W. Featherstonhaugh thus described 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 quantities 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 in width. There is a very smooth section of the rocks here to the water, about ninety feet. I should think the fall would not average more than twenty feet. * * * * 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.

In another place** Mr. Featherstonhaugh indulges in the following reflection on the recession of the falls of St. Anthony.

The observant traveler who ascends the Mississippi from the point where the escarpments first appear, sees in them the results of an operation of one and the same kind, and when at length he overtakes the cataract he sees in it the powerful natural agent which has excavated the valley he has followed

* Report of a geological reconnoissance made in 1835 from the seat of government to the coteau de prairie, p. 136.

** Canoe voyage up the Minnay Sotor, vol. i, p. 276.

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** Canoe voyage up the Minnay Sotor, vol. i, p. 276.

so great a distance. But if, desirous of computing a period within our own chronology for the accomplishment of so stupendous a work, he were to assume nothing beyond the force now in action, he would find himself baffled beyond all hope of extrication. Father Hennepin found these falls, 164 years ago, at the same place, as far as we can understand him, where they are now. Carver, who visited them in 1766, now seventy-eight years ago, speaks of the small island near the centre of the cataract, though rating its dimensions, as he did the hight of the fall, very inaccurately. So that we are, perhaps, within bounds, when we suppose that the cataract has not receded more than twenty yards in the last 100 years, and probably not more than 400 yards in the last 2000 years. If the waters of the Mississippi then had never been more powerful than they are at present, how many millions of years must have elapsed during the accomplishment of this long excavation, especially if we make allowances for the hight and breadth of the valley south of the falls of St. Anthony which exceed fourfold those at the point which the cataract now has reached. It would seem, therefore, to be a vain attempt to assign any portion of the mysterious past for such a work as the excavation of the channel of the Mississippi.

It is only necessary to say that Mr. Featherstonhaugh here refers to the width of the gorge, and its depth, at points below Fort Snelling, "where the escarpments first appear." He regarded the limestone that forms the brink of the falls now as identical with the carboniferous limestone of Illinois, and thought it very interesting to the geologist because of its uninterrupted continuation for one thousand miles along the upper bluffs of the river. He noticed neither the changes that took place in the strata, as he ascended the river, as one after another of them disappeared from the bluffs, nor the marked distinctions in the drift. The greater width of the river below Fort Snelling is a remarkable fact, here appealed to, to set that part of the gorge off from that which lies above that point, the width of which does not vary materially throughout all the distance up to the falls. He also certainly misinterpreted Hennepin and Carver in their descriptions, as will appear.

All the measurements of the width of the river given by Mr. Featherstonhaugh should be reduced by one half. His measurements, or estimates, aggregate 3360 feet for the total width of the river, including Hennepin island, whereas a trigonometric determination by Prof. M. D. Rhame makes the total width, in 1876, about 1700 feet.

Boutwell's description, 1832.

Rev. W. T. Boutwell, who accompanied the expedition of H. R. Schoolcraft to the source of the Mississippi in 1832, kept a daily journal of events. This has been published by the Minnesota Historical Society,* and its description of the falls of St. Anthony is more useful for this investigation than the journal either of Mr. Schoolcraft or of Lieut. Allen. This description was made July 25, 1832. The island here mentioned must have been Hennepin island.

* Collections of the Minnesota Historical Society, vol. 1, p. 153.

The stream is divided in abont its centre by a bluff of rocks covered with a few trees. The perpendicular fall is perhaps twenty feet on each side of this bluff, at the foot of which there is a shoot of some ten or fifteen feet more in a descent.

Mr. Schoolcraft's notes, made at the same time, consist of the following lines:

The fall itself is an imposing exhibition of geological scenery. The river here sinks its level about forty feet in a distance of say 1500 yards. Sixteen feet of this has been estimated to consist of a perpendicular fall, reaching, with irregularities, from shore to shore. Debris is accumulated in rude masses below, and the rapids are filled with fallen or rolled rocks which impart a character of wildness to the scene. We made a portage of 1250 yards, having descended nearer to the brink of the fall than is common.

Prof. Wm. Keating's measurements, 1823.

In 1823 Major Stephen Long made his second visit to the falls of St. Anthony. Of this visit Prof. William Keating, who accompanied the expedition, made the following comment on the falls of St. Anthony.*

An island, stretched 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 the nature of the rock, which breaks into angnlar, and apparently rhomboidal, fragments of a large size, this fall is subdivided into small cascades which adhere to each other so as to form a sheet of water unrent bnt composed of an alternation of retiring and salient augles, and presenting a great variety of shapes and shades; * * * * Mr. Colhoun measured it [the hight of the fall.—N. H. W.] while we were there with a rough water level, and made it about 15 feet. * * * * Messrs. Say and Colhoun obtained an approximate admeasurement [of the width of the whole river.—N. H. W.] of five hundred and ninety-four yards. This resulted from a trigonometrical calculation, the angles having been measured with a compass that was small and not nicely graduated, and the base line having been obtained under unfavorable circumstances. Below the fall the river [i. e. the actual water channel.—N. H. W.] contracts to about two hundred yards. * * * *

The falls are occasioned by the fissures which occur in the Superior limestone and which allow the water to penetrate through this bed to the sandstone, which, being of a loose texture, is soon washed away; in this manner thick plates of limestone are left unsupported and soon fall by their own gravity. This process is constantly causing the fall to recede towards its source. What length of time has been required to bring the falls to their present situation it is not in the power of man to ascertain; but we may well see that it must have been immense.

It appears by this descripton that the falls in 1823 were nearly the same as in 1835. The island separating the fall into two parts was nearer the east bank than the western. Moreover the measurements given are nearly correct, the error of over-estimating being probably confined to the east channel. The whole width, the sum of the estimates, is 1920 feet, but according to the rough triangulation, 1782 feet.

It is noteworthy that Mr. Beltrami, who was one of Major Long's party at the time Mr. Keating made his description, is the only one to note the existence of a little island in the river below the falls. With a great deal of verbi-

* Narrative of an expedition to the sources of the St. Peter river, lake Winnepeek, Lake of the Woods, etc., performed in the year 1823, vol. ii, p. 306.

age, Mr. Beltrami's description can still be interpreted, and actually is applicable to the various objects about the falls.*

Beltrami's description, in 1823.

Seated on the top of an elevated promontory [say the university bluff.—N. H. W.] I see at half a mile distance two great masses of water unite at the foot of an island [the two channels inclosing Hennepin island.—N. H. W.] 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 [i. e. above the rapids.—N. H. W.]. From this point they rush down a rapid descent about two hundred feet long [rapids above the falls.—N. H. W.] and, breaking against the scattered rocks that obstruct their passage, they spray up and dash together in a thousand varied forms. Then they fall into a transverse basin in the form of a cradle and are urged upward by the force of gravitation against the side of a precipice [some rent in the limerock on the brink of the falls, one of the zigzag notches described by Keating.—N. H. W.] which seems to stop them a moment only to increase the violence with which they fling themselves down a depth of twenty feet [the falls of St. Anthony.—N. H. W.]. The rocks against which these great volumes of water dash [the rhomboidal fallen masses of limerock.—N. H. W.] throw them back in white foam and glittering spray; then plunging into the cavities which this mighty fall has hollowed [i. e. the openings between the fallen blocks.—N. H. W.] they rush forth again in tumultuous waves, [i. e. the rapids below the falls.—N. H. W.] and once more break against a great mass of sandstone forming a little island [i. e. Carver island.—N. H. W.] in the midst of their bed, on which two thick maples spread their shady branches.†

Schoolcraft's description in 1820.

At the time of Mr. Schoolcraft's first expedition to the sources of the Mississippi, made in oonjunction with Gov. Lewis Cass, he sketched the falls of St. Anthony and wrote a description. These were published in the Albany edition of his "Narrative Journal," in 1821. The description is in the following terms, and the illustration is reproduced *fac-simile* in plate V.

The falls of St. Anthony are fourteen miles below the confluence of the Mississawg aligon. We reached the upper end of the portage at half-past eight in the morning, and while the voyageurs were busied in the transportation of our baggage, hastened to take a view of this celebrated cataract. The river has a perpendicular pitch of forty feet, with a formidable rapid above and below. An island at the brink of the falls divides the cataract into two sheets, the largest of which passes on the west of the island. The rapid below schute is filled with large fragments of rock, in the interstices of which some alluvial soil has accumulated, which nourishes a stinted growth of cedars. This rapid extends half a mile, in which distance the river may be estimated to have a descent of fifteen feet. The rapid preceding the falls has a descent of about ten feet in the distance of three hundred yards, where the river runs with a swift but unruffled current over a smooth stratum of rock a little inclined towards the brink. The entire fall, therefore, in a little less than three-fourths of a mile is sixty-five feet. The rock is a white sandstone overlaid by a secondary limestone. This formation is first seen half a mile above the falls where it breaks out abruptly on the banks of the river. The perspective view (plate VII) is taken from a point about two hundred yards below the schute of the falls on the east shore and a short distance west of the portage path. The scene presents nothing of that majesty and awe which is experienced in the gulf below the cataract of Niagara. We do not hear that deep and appalling tone in the roar of water, nor do we feel that tremulous motion of the rocks under our feet which impresses the visitor at Niagara with an idea

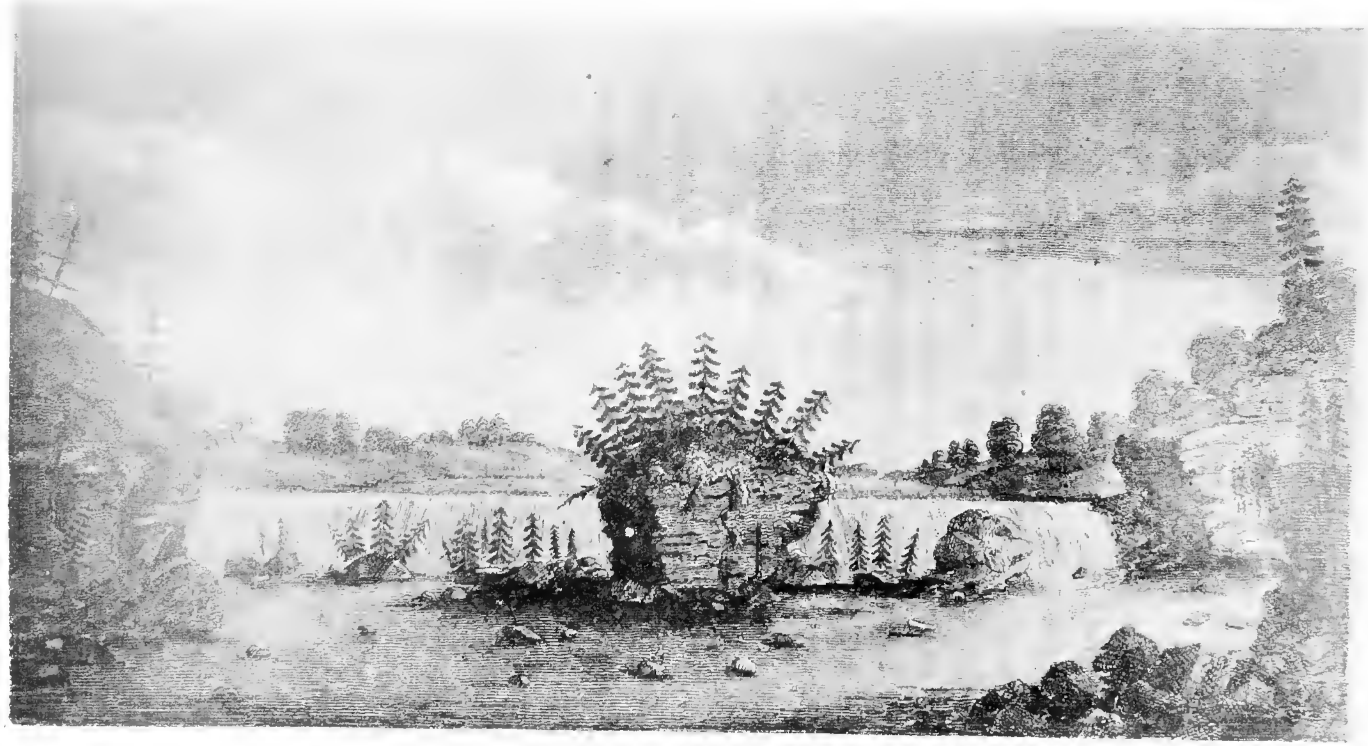
* A pilgrimage in Europe and America, leading to the discovery of the sources of the Mississippi and Bloody river. J. C. Beltrami. London, 1828. vol. 2, p. 205.

† The following is quoted from the French edition of Beltrami's *La Découverte*, published by him at New Orleans in 1824, immediately after his return from the upper Mississippi:

Quel nouveau spectacle s'offre à mes yeux, Comtesse! n'etant ni peintre ni poëte, comment pourrai-je le rendre! J'en tracerai le canevas de mon mieux, et votre imagination fertile fera le reste.

Assis sur le sommet d'un promontoire élevé je vois, à la distance d'environ un demi mille, deux grandes masses d'eau se

PLATE V.



SCHOOLCRAFT'S FALLS OF ST. ANTHONY—1820.

of *greatness* that its magnificent outline of rock and water would not, independently, create. The falls of St. Anthony, however, present attractions of a different nature, and have a simplicity of character which is pleasing. We see nothing in the view which may not be considered either rude or picturesque, and perhaps there are few scenes in the natural topography of our country where these features are blended with more harmony and effect. It is in fact the precise point of transition, where the beautiful prairies of the upper Mississippi are merged in the rugged limestone bluffs which skirt the banks of the river from that point downward.

* * * * * * * * * * * * *

It is probable, too, that during the high floods of the Mississippi in spring and fall, this cataract attains a character of sublimity, from the increased volume and tumult of the water, and the inundation of the accumulated debris, which presents at this season so rugged an aspect. It is said also that this accession of water produces a cloud of spray which must take away a certain nakedness in the appearance of the falls that will strike every visitor who has previously enjoyed the sight of Niagara.

* * * * * * * * * * * * *

At the east side of the river, close under the sheet of the principal column of water, the Indians procure a kind of clay of a brownish red color with which they paint their canoes and baskets. It appears to be an aluminous substance very much mixed with iron pyrites in a state of decomposition, and penetrated with vegetable juices. It is found in a crevice about ten feet below the water, and they pretend that it is renewed when taken away.

It is evident that Mr. Schoolcraft aimed, like Carver, whose general looseness and verbose style of composition his pages continually recall, to *make a good picture*. There is abundant evidence of the inaccuracy, and incompleteness of this illustration. The island dividing the falls contains nothing, in the form of foliage, except that of coniferous trees, and those are arranged in a divergent semicircular row after the manner of the head-gear that expresses the brave deeds of an Indian chief; but the trees native to the region, even along the immediate banks of the river, are mainly not coniferous but deciduous. The alluvial islands which Pike and Long saw, a few years before this sketch was made, and which existed in 1851, and have continued even to this day in a modified form, are not shown in the sketch, though they may be referred to in the *fallen rocks and the interstitial soil that supported a stinted growth of cedars.* Spirit island, as such, is not represented, but it may be supposed that from the position at which Mr. Schoolcraft made the sketch, it would so overlap the west end of the falls that in the view presented it forms the apparent west bank of

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réunir aux pieds d'une île, qu' elles embrassent, et dont les arbres majestueux repandent sur elles des nuanees, oú l' Ombre, et la Lumière jouent tour-a-tour d'une manièra tonte magique. De là, elles coulent sur une pente rapidc, qui continue l'espace de deux cent pas, et, se brisant contre des rochers, qui, cpars ça et là, génent leur passage, elles jaillissent, et se heurtent de mille manières differentes.

Elles entrent ensuite dans un bassin transversal, en forme de berceau, et, poussées par la force de la gravitation, elles remontent, et rencontrent le bord d'un precipice, qui semble les arreter un instant, pour augmenter la violence, avec laquelle elles s'élancent dans une profondeur de 20 pieds. Des rochers, sur lesquels ces grands volumes de fluide vont se briser, les blanchissent en les repoussant, et en éparpillent des jets rayonans. S'engouffrant ensuite dans des cavites, que cette grande chûte a creusées, its en ressortent en bouillonant à grands flots, et vont se briser encore contre une grande masse de tuf qui forme une petite île au milicu de leur lit, sur laquelle deux érables touffus étendent leurs rameaux, en forme de bouquet.

La scene est sur le Mississippi, et c'est lui-même qui en est le grand acteur. C'est là l'endroit, qu' on appele *the falls of St. Anthony* les chutes de St. Antoine, à 8 milles audessus du Fort; nom qui doit, je pense, lui avoir été donnée par le pere Hanepin pent-être pour célébrer le jour de la découverte.

Un moulin des petites chaumières que le colonel y a fait bɛtir, pour l' usage de la garnison et ces alentours, rcvêtus de scènes romantiques, achevent le grand tableau.

the river. There is also an indication of this in the varying distinctness of the perspective representation. The island here shown in the brink can then, be no other than Hennepin island.

Major Stephen H. Long's description of the Falls of St. Anthony in 1817.

Major Stephen H. Long visited the falls of St. Anthony in 1817. His description was published in 1860 by the Minnesota Historical Society, and is contained in volume ii. of its collections. This makes distinct mention of Spirit island, and also agrees with Keating's account in the relative widths of the east and west channels. The two islands here mentioned in the west channel must have been Cataract and Carver islands, the latter of which Major Pike saw in 1805 dividing the shoot in the west channel, and which Carver also shows in his sketch made in 1766.

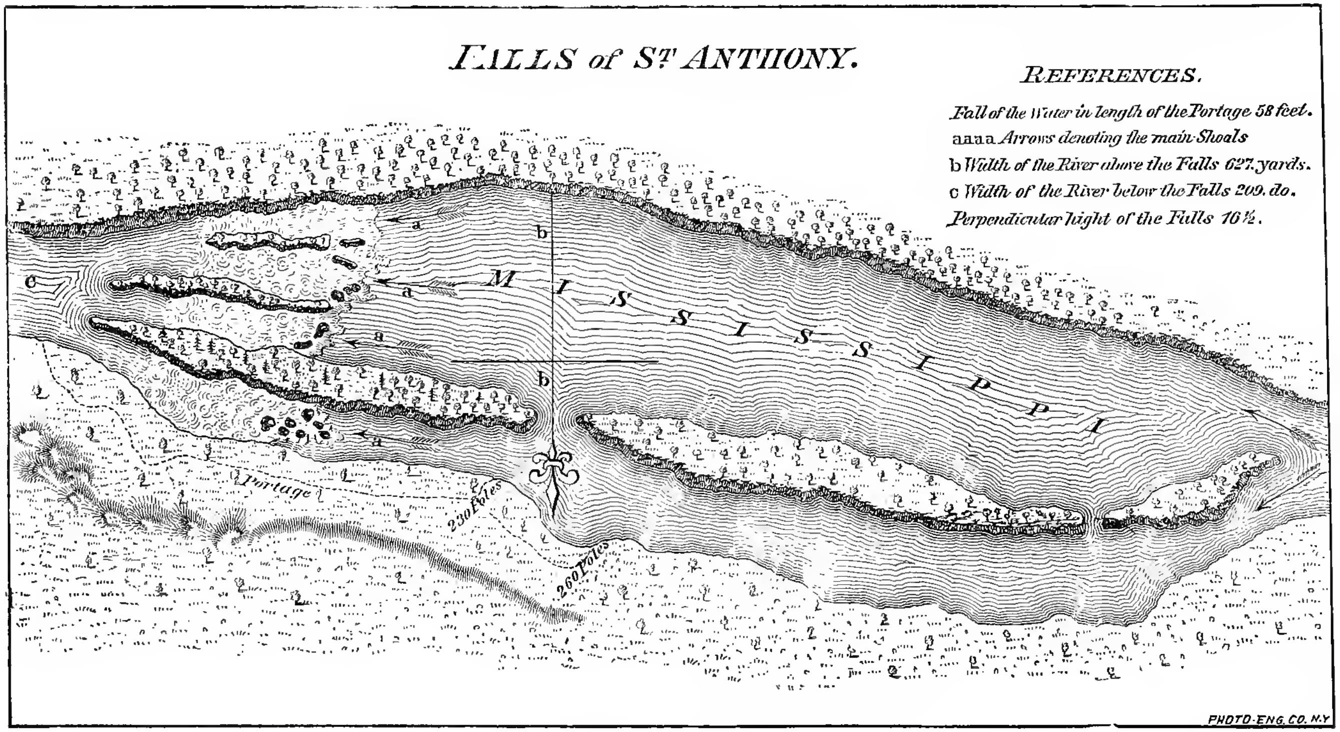
The perpendicular fall of the water at the cataract, as stated by Pike in his journal, is sixteen and a half feet, which I found to be true by actual measurement. To this hight, however, four or five feet may be added for the rapid descent which immediately succeeds the perpendicular fall within a few 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 five hundred yards long. 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 them 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 instruments 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 hight 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.

Major Z. M. Pike at the Falls of St. Anthony in 1805.

In a letter to general Wilkinson at St. Louis, dated September 26th, he gives a general description, a *coup d'œuil*, as he styles it, of the appearance of the falls, in the following words.*

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 five hundred yards above; the river then falls through a continued bed of rocks, with a descent of at least fifty feet perpendicular in the course of half a mile—from thence to the St. Peter's, a distance of eleven miles by water, there is almost one continued rapid, aggravated by the

* An account of expeditions to the sources of the Mississippi, and through the western parts of Louisiana, etc., during the years 1805, 1806, and 1807, by Major Z. M. Pike, Philadelphia, 1810. Appendix, pp. 13 and 51.



PIKE'S PLAN OF
ST. ANTHONY FALLS
1805.

interruption of twelve small islands. The carrying-place has two hills, one of twenty-five feet, the other twelve, with an elevation of forty-five degrees, 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, continues about half a mile above the shoot, when the water becomes calm and deep.

Plate W. is a *fac simile* reproduction of his drawing intended to show a plan of the river at this place. This plan confirms the interpretation already given of the descriptions of those that followed him. It is found in the thin atlas-volume with other maps of his travels, accompanying the first edition of his work. This shows Boom island, Nicollet island and Hennepin island, the last dividing the falls and extending as far below the brink as the lower end of Spirit island. Cataract island is thus shown as a part of Hennepin island. Spirit island is long and narrow, running nearly up to the brink. Carver island, near the west shore (known in 1854 as Upton island) is about half as long as the representation of Spirit island, is also narrow and begins at a point further from the brink than the upper end of Spirit island. At the foot of the cataract are shown numerous large detached rock-masses. The brink of the chute forms a very crooked line, both in the east and in the west channel. The islands are all timbered. The west shore is timbered. The east shore has a few scattering trees. The portage trail is represented on the east shore, beginning a little below the foot of Hennepin island and extending to the upper end. The low-water landing, at the upper end of the trail, was a little above the lower end of Nicollet island.

The little island "on the west" which he stated divided the shoot, is not so shown. In general too much length is given to all these islands.

Having made some careful measurements he gives the following dimensions in the appendix to his narrative.

On actual survey I find the portage to be two hundred and sixty poles, but when the river is not very low boats ascending may be put in thirty-one poles below, at a large cedar tree, which would reduce it to two hundred and twenty-nine poles. The hill over which the portage is made is sixty-nine feet ascent, with an elevation at the point of debarkation of forty-five degrees. The fall of the water between the place of debarkation and re-loading is fifty-eight feet. The perpendicular fall of the shoot is sixteen and a half feet. The width of the river above the shoot is six hundred and twenty-seven yards; below two hundred and nine. For the form of the shoot see a rough draft herewith.

Carver's view of the Falls of St. Anthony, 1766.

Prior to the visit of Major Pike the next earlier account is that of Jonathan Carver, who saw the falls in November, 1766, and whose sketch of them was engraved to accompany his *Travels*, published in London in 1778.* The dedication of his work to Sir. Joseph Banks, Esq., by Capt. Carver, is dated

* Travels through the interior parts of North America in the years 1766, 1767 and 1768, by J. Carver, Esq.

June 20, 1778. This engraving was reproduced in the Dublin edition of his *Travels* in 1779, in Wm. Winterbottom's *View of the United States of America*, in 1796, and again in the New York edition (Harper and Brothers), in 1838, but though the main features are preserved, this representation undergoes some changes in the course of the successive editions. It was again presented in *Harper's New Monthly Magazine*, for October, 1875, and wrongly attributed to father Hennepin. It is seen in vol. i. of this report, page 22, and in *Neill's Concise History of Minnesota*, 1887. Plate X is a representation of Carver's sketch by photo-lithography, from Harper's edition of 1838.

The only island above the falls represented by Carver, though it is not mentioned in his description, is some distance above the brink, and near the western shore. It is plain that he intended this for an island, though it was placed so near the shore that it was engraved in some of the editions as a peninsula from the west bank, from the fact that it is shown covered with trees—the only trees about the place being those on the island or close by the river banks. Besides this he shows two other islands distinctly. One is a small, high, rocky island, dividing the shoot, bearing a few trees, and the other is a large, circular, low island below the falls, covered with timber. Besides these, which he unhesitatingly styles islands, there is another which he represents as an apparently detached block of limerock lodged on the brink, between the small, rocky island and the eastern shore.

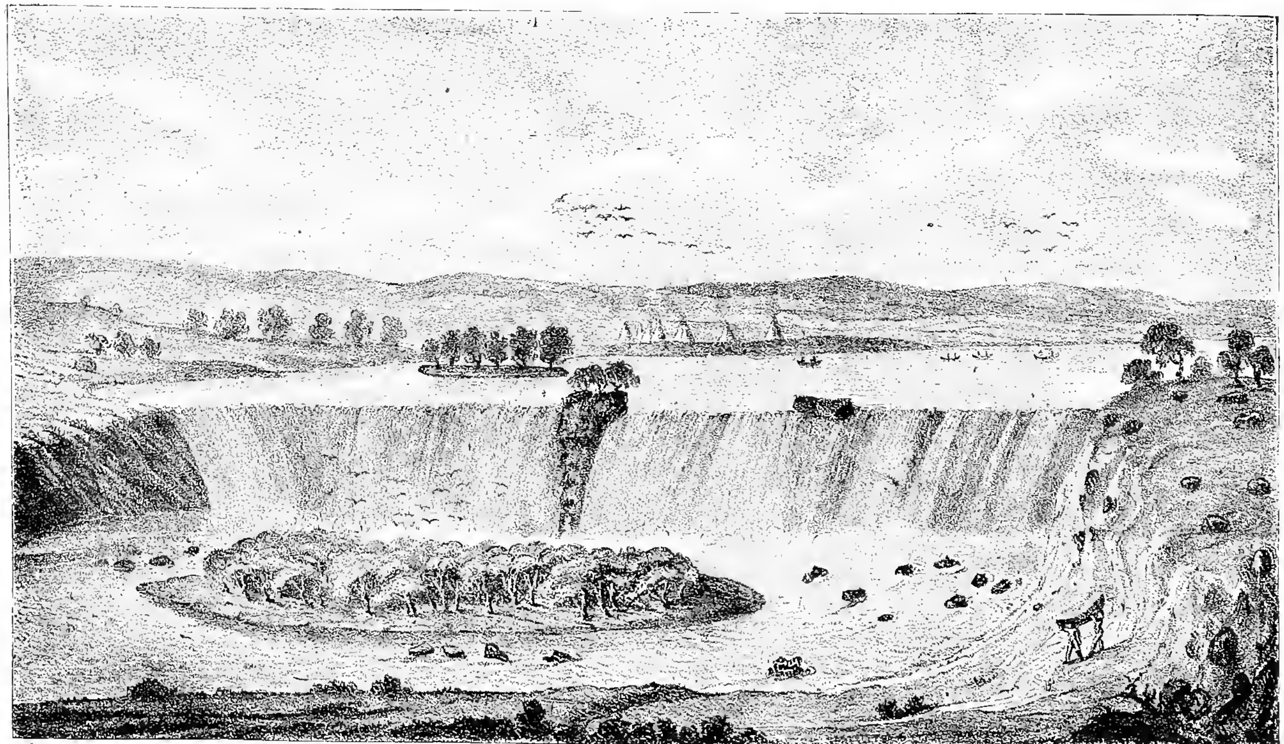
Of this engraving by Carver it is necessary to make the following remarks, since, to say the least, it is remarkable for its inaccuracies as much as for its historic value.

1. It was drawn from memory, after he had left the place, and that will account for its inaccuracies. He probably did not make even a pencil sketch. The careful reader of Carver's book will notice that he speaks of all events, and writes his descriptions of transient objects with verbs in the past tense. The following quotations will show this habit:

"On the first of November I arrived at lake Pepin which is rather an extended part of the river Mississippi," etc.

"One day, having landed on the shore of the Mississippi some miles below lake Pepin, I walked out to take a view of the adjacent country," etc.

"About thirty miles below the falls of St. Anthony, at which I arrived the tenth day after I left lake Pepin," etc.



Survey'd by Capt. Carver Nov. 17. 1766 — M. A. Rooker Sculp.

The falls of St. Anthony in the River MISSISSIPPI near 2400 Miles from its entrance into the Gulf of Mexico

Height of the Fall 30 feet Perpend.r

Breadth near 600 feet.

Published as the Act directs by J. Carver 12 May 1778.

The following is his description of the falls, and this manner of expression is seen running through it:

Carver's description of the Falls of St. Anthony.

This amazing body of waters, which are above two hundred and fifty yards over, form a most pleasing cataract; they fall perpendicularly about thirty feet, and the rapids below, in the space of three hundred yards more, rendered the descent considerably greater. * * * * * * in the middle of the falls stands a small island, about forty feet broad, and somewhat longer, on which grew 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 long. * * * * 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.

2. The timbered island, represented near the left bank some distance above the falls, must be intended to represent Hennepin island, and should be near the right bank, just above where the oblique rock is shown in the brink of the falls. There is no island where it stands now, nor is there any evidence that there ever was one; on the other hand every later traveler, who has described the falls since Carver, has mentioned an island extending above the falls separating the river, and finally the shoot, into two unequal parts.

3. The view which Carver gives is intended to show the whole width of the river, and not the west channel only, as has been supposed by some. The evidence of this consists in four facts. 1st. He asserts that he has "endeavored to give the reader as just an idea of this enchanting spot as possible in the plan annexed," and it is hence necessary to suppose that he would make it in the main corroborate the statements of his written description. 2d. The illustration shows a continuous shore-line, extending from above the falls, along the front, to the left-hand side, as a river-bank would have to be, and as no island could be drawn. 3d. The shore-line so represented is nearly treeless, as it is known to be in nature, whereas if it had been intended to show Hennepin island it should have been timbered. 4th. The cut shows two men carrying a canoe along a well-marked portage-trail. Anyone who has traveled over the western waters by canoes, under the guidance of the aborigines, can bear testimony to the worn condition of the portage-trails and the permanence with which they are kept in the same positions from year to year. This is the same trail over which major Pike dragged his boats in 1805, up which major Long walked in 1817, down which Boutwell and Schoolcraft paced the distance in 1832, and down which Featherstonhaugh walked to his boat when he returned to Fort Snelling in 1835. Now, such a circumstance as the port-

age-trail being over an island, had it been true, would have been mentioned by some of these travelers, if not by all of them. Not one of them alludes to that fact, but, on the contrary, some of them distinctly say they passed round the cataract on the east shore. Major Pike's plan of the falls actually shows the portage trail on the main shore running on the east bank.

4. The large island below the falls, on which Carver says so many eagle nests were found by him, can be no other than Spirit island. This was still the abode of eagles in 1849 and 1850, when early settlement began. His representation of this island as low and alluvial, when in reality it was composed, as now, of sandrock and limestone strata rising as high as the brink of the falls, rendered somewhat necessary to avoid the hiding of the falls from the point of view from which the sketch was made, would be no unusual error, and would hardly be regarded an imperfection by any but a geologist or a professional artist. There is no other island in the river to which this represented by Carver could be referred. If there had been any other island similar to Spirit island, which is mentioned by nearly everyone who has described the falls, that fact certainly would not have escaped mention by every one of them. Neither could there have been any island above the brink of the falls at this part of the channel, when Carver was here, which by recession could have been brought, at the time of Pike and Keating and others, into the position in which Spirit island now is; since, if such island had existed, there would now be two such islands below the falls instead of one. The accounts are all concordant if this low island be considered to be what is now known as Spirit island, and are unadjustable with the facts if it be not so considered.

5. The little rock-island which is shown in the brink of the falls just above Spirit island is an important link connecting Carver's description with Pike's and Long's. It is worthy of being called Carver's island. Pike saw it there "dividing the shoot," in some such manner as represented by Carver's sketch; by the time Long was there, in 1817, it was only an insignificant island at the base of the cataract, the debris only of the rock-barrier which once rose perpendicular to the brink and supported trees on its summit. The debris from this island has remained to this day as an alluvial island in that part of the river, but it has been much modified, and enlarged by rock and dirt from the excavations that have been made for the improvement of the water-power.*

* Mr. J. W. Bond, in *Minnesota and its resources*, p. 152, says: "Below the falls are two small islands near the right shore," meaning Carver and Spirit islands. This book is dated 1853.

6. The oblique rock which Carver's sketch shows in the eastern part of the falls, which he states appeared to be five or six feet broad and thirty or forty long, could not have been any movable or detached piece. It is more likely that it was one of the oblique edges of the frequent rhomboidal blocks into which the limerock is known to separate along the brink prior to its downfall. The descriptions of Keating and of Featherstonhaugh, and chiefly the daguerreotypes of Hesler, already referred to, are sufficient evidence of the zigzag course of the margin of the fall as it is traced from one side to the other. It is probable that one of these blocks projected further and more persistently than any of the others, and thus became exposed above the level of the rapidly running water as it hurried over the brink.

7. It is highly probable that the effect of Hennepin island, situated in the river immediately above this oblique rock as noted in (2) above, tended to divert the current from this part of the brink, and to prolong its existence. This rock thus protected, connected under the water above the falls continuously with the rock which underlay Hennepin island itself, would gradually be more and more protected, as the brink receded nearer the island, and would become wider and wider. At last the waters would be divided continuously by dry land extending from it to the island, and it would become a part of the island. Hence it is reasonable to suppose that it represents the toe of Hennepin island at the time of Carver's visit, the intervening portion of the foot being still submerged. This serves to fix the position of the falls, at this date, near the foot of Hennepin island, though there was doubtless a broad curve upward on the west of this island, as described by late observers, which would place the island dividing the falls (Carver's island) a considerable distance above Spirit island.

The discovery by Hennepin, 1680.

Before Carver there is no record of the appearance of the falls except that of father Hennepin who discovered them July 5, 1680. He gave this brief description of his great discovery:

> In ascending this river ten or twelve leagues, navigation is interrupted by a fall, which we named in honor of St. Anthony of Padua, whom we had chosen as patron of our enterprises. This fall is 50 or 60 feet in hight, and has an island of rock, in the form of a pyramid, in the middle of the chute.*

---

* See the Amsterdam edition of Hennepin's works, 1704, chapter 44, p. 319. A translation of Hennepin's narration is found in the *Historical Collections of Louisiana, Part IV*, in which he gives "40 or 50" feet as the hight of the fall.

Hennepin preceded Carver eighty-six years. Carver preceded the date at which this investigation is limited by the advent of settlement by whites (1856), ninety years. It is not probable that the whole recession accomplished in eighty-six years would exceed that in the following ninety years. If it be equal to it, the falls were seen by Hennepin when Spirit island divided them. The statements of Hennepin do not indicate at what point in Spirit island the falls were when he saw them. In the former discussion of this recession* a point was assumed near the centre of the island and the amount of recession between Carver and Hennepin was calculated from that datum, the result being that the recession between Carver and 1856 was more than twice that between Carver and Hennepin. It is plain, however, that there could not have been that difference. In consideration of the actuality of a small island distinct from Spirit island, just above Spirit island, which was not recognized then, it is allowable to move upward the line representing the brink at the time of Carver. Hennepin's brink also might be moved a hundred feet further down, if the facts required it, and still be within the limits of Spirit island. These variations do not materially affect the result, and will introduce a little more consistency, in detail, with the historical records.

Data for fixing the rate of recession.

In 1856. It is pretty well known where the falls were in 1856. In the brink there was one island (Hennepin), about one-fourth of the water passing down the east channel. Near the foot of this island, but somewhat toward the west from it, was Cataract island, a low island formed by fallen debris. It was covered with trees, and in time of low water was connected with Hennepin island. Further west still, nearly in a line above Spirit island, near the base of the cataract, was a low island of rocky debris, on which also grew some trees.† Spirit island, high and rock-formed, topped with trees, was below the brink in the west channel, some distance below Carver island. Eastman's, Lœmans' and Hesler's views illustrate this condition of the falls. The view of Lewis is less particular, and has omitted Carver's island, unless it may be supposed to be hid by Spirit island.

Featherstonhaugh in 1835. An island 450 yards long divides the fall unequally; east channel 220 yards wide, west channel 450; fall 20 feet average.

* Fifth annual report of progress.

† This is here designated Carver's island.

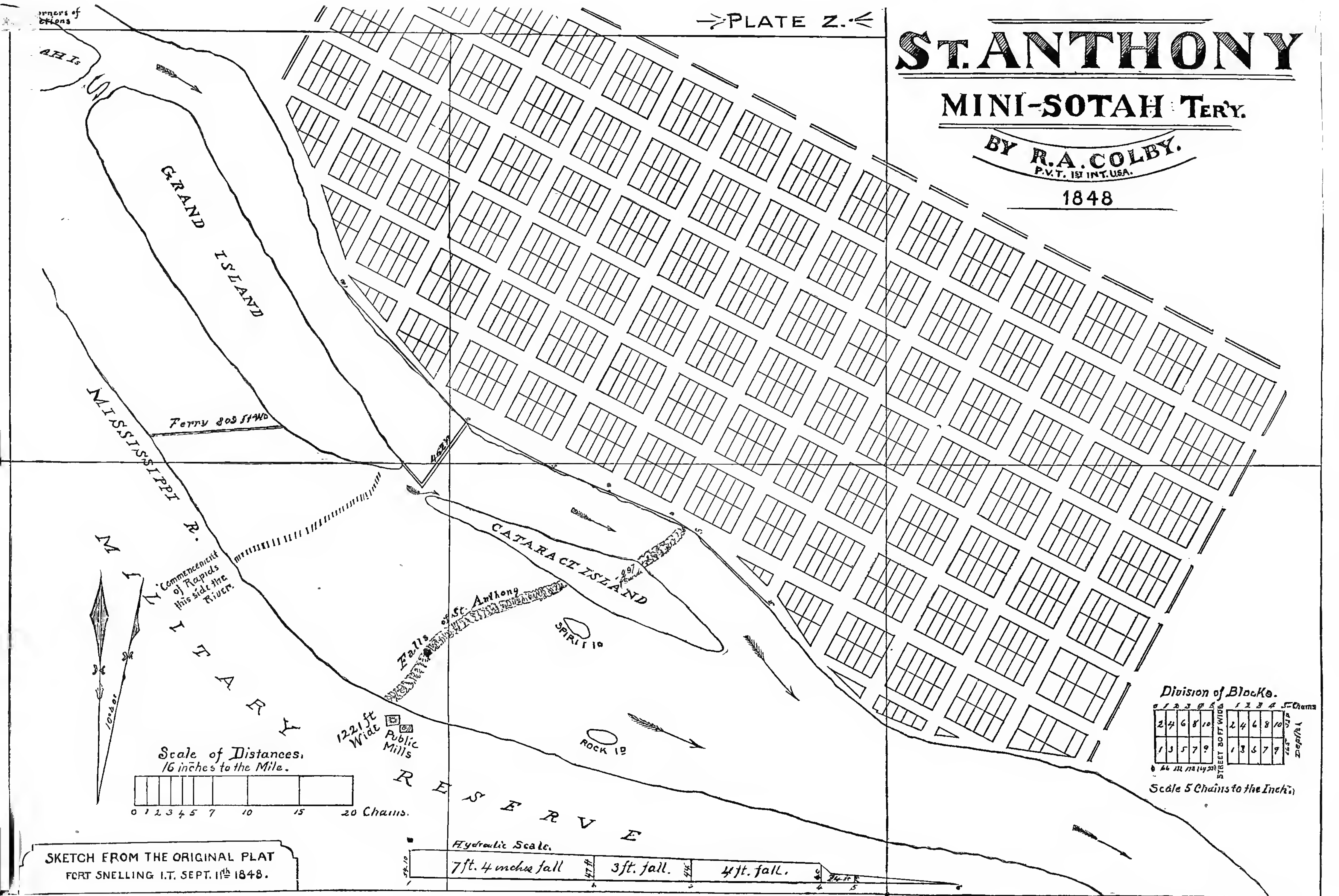


PLATE Z.
ST. ANTHONY
MINI-SOTAH TER'Y.
BY R. A. COLBY.
P.V.T. 1ST INT. U.S.A.
1848
GRAND ISLAND
Ferry
MISSISSIPPI R.
Commencement of Rapids this side the River.
CATARACT ISLAND
Falls of St. Anthony
SPIRIT Id
ROCK Id
1221 ft Wide
Public Mills
MILITARY RESERVE
Scale of Distances.
16 inches to the Mile.
0 1 2 3 4 5 7 10 15 20 Chains.
Hydraulic Scale.
7 ft. 4 inches fall
3 ft. fall.
4 ft. fall.
Division of Blocks.
STREET 80 FT WIDE
Scale 5 Chains to the Inch.
SKETCH FROM THE ORIGINAL PLAT
FORT SNELLING I.T. SEPT. 11th 1848.

Boutwell and Schoolcraft in 1832. A bluff of rocks about at the centre of the falls; perpendicular fall about twenty feet; portage 1,250 yards.

Keating in 1823. Island separates the river into two unequal parts; the eastern 230 yards wide, the western 310; the island itself is about 100 yards wide; perpendicular fall fifteen feet; whole width of the river 594 yards; river below the falls 200 yards.

Beltrami in 1823. Only distinctly mentions an island in the brink and another of sandstone below the falls on which grew maples.

Schoolcraft in 1820. Perpendicular pitch 40 feet, with rapid above and below, the whole descent being 65 feet. An island, east of the middle, divides the falls into two sheets. Large fragments of rock, with soil and trees, in the rapids below the cataract.

Long in 1817. Island 500 yards long divides the cataract and river above and below the falls; channel on the west side three times that on the east side; one-third of the water descends the east channel; waterfall 16½ feet. In the broadest channel, just below the cataract, is a small island, 50 yards by 30; both islands rocky, with the same formations as in the banks, "and nearly as high;" two others of inconsiderable size immediately at the foot of the falls, both in the right channel.

Pike in 1805. Portage 260 poles; waterfall 16½ feet; width of river above the falls 627 yards; below 209; one large island on the east, and a small one on the west, each dividing the shoot, the former commencing below the shoot and extending 500 yards above; twelve islands in the distance of eleven miles below.

Carver, 1766. Width of river 250 yards (or "about 600 feet"); hight of the fall 30 feet; a small island in the middle of the fall 40 feet broad and "somewhat longer," with hemlock and spruce trees, and another of an acre and a half a little below the falls, with great quantities of eagles' nests; an island also above the falls; an oblique rock in the brink of the falls half way between the island and the east shore, "about five or six feet broad and thirty or forty long."

Hennepin, 1680. Pyramidal island in the middle of the fall. Hight of fall 50 or 60 feet (or "40 or 50 feet").

Conclusion.

Hennepin saw the falls in 1680 when Spirit island divided them, and their hight was much greater than now. The river gorge is 1,350 feet wide across Spirit island, but it becomes narrower immediately below. It is probable that the confinement of the water in this narrower channel caused the greater hight of the falls. It is very likely that the falls were near the foot of the island. This is probable from the necessity of considering the recession between Hennepin and Carver nearly equal to that between Carver and 1856, the times being nearly equal. It is also probable from the manner of Hennepin's brief description. He says it was "an island of rock in the form of a pyramid" that divided the falls. This terse description would not have been applicable if there had been a stream of debris lodged in the lee of the island supporting trees, as is now seen below Hennepin island; and this stream could only be absent when the recession first brought the brink up to the island. The appearance was due to the same circumstance as that which protruded the toe of Hennepin island in the brink when Carver saw the falls in 1766, but the recession had so far entered upon the island that the island was not entirely encircled by water above the falls.

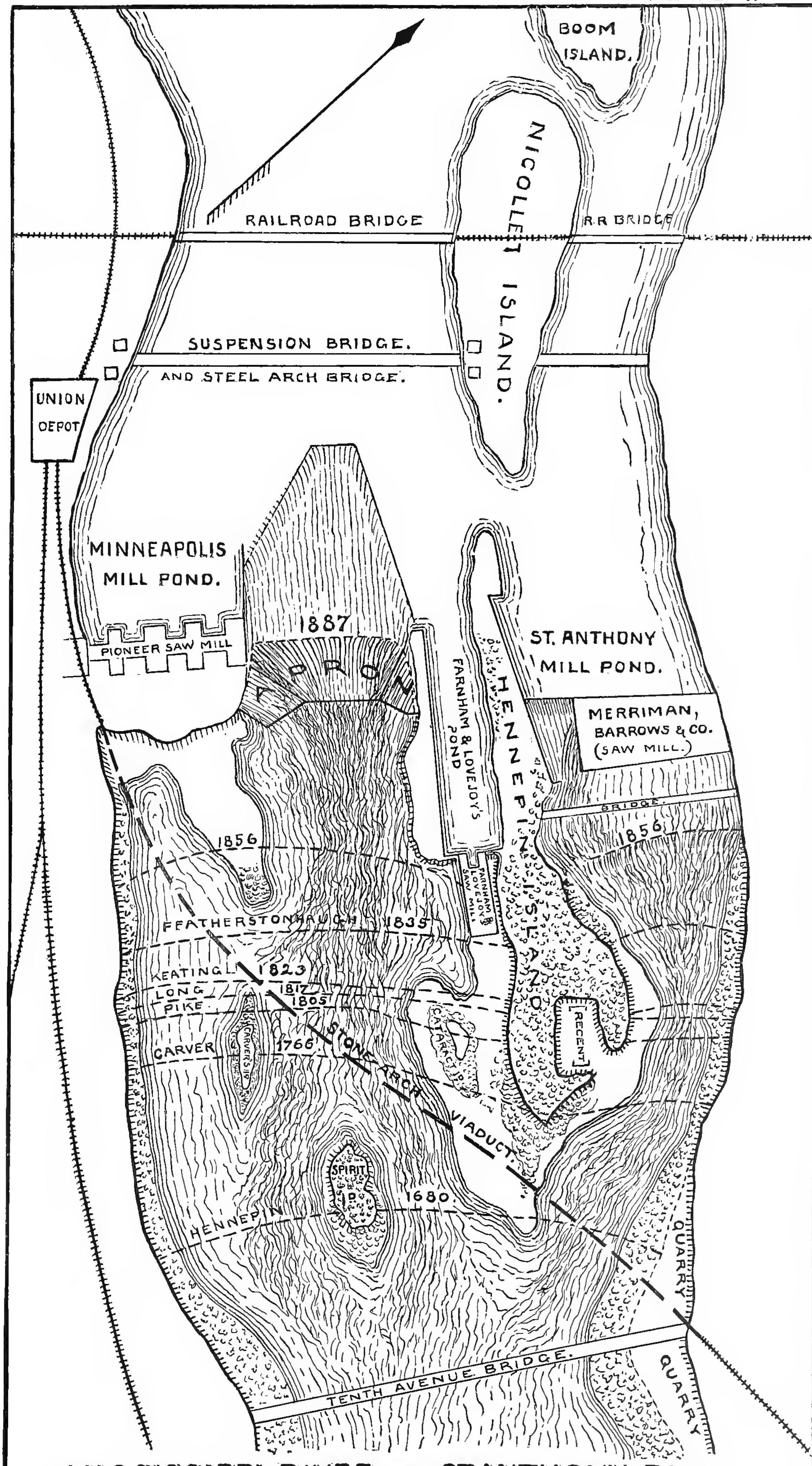
When Carver saw the falls the "oblique rock" was the beginning of Hennepin island. The debris which is in the lee of this island is no indication that the island ever extended so far below. The lower end of the rocky undisturbed platform of Trenton limestone may be assumed with a great degree of probability, as in the exact brink at this date. The small island in the middle of the fall seen by Carver about in a line directly above Spirit island, represented by him as formed of rock-strata in place was reduced soon after Pike's visit in 1805, to a mass of debris, and disappeared from the brink.

There is no way of fixing the intermediate points, when the brink was seen by Pike, Long, Schoolcraft, Beltrami and others, prior to 1856, nor is there any need of it. The particulars of their descriptions have been given to show the continuity of detailed historic description, and the necessity of the interpretations here proposed, and the rate deduced.

From the foot of Hennepin island the falls receded, between 1766 and 1856, to a position about the centre of Farnham and Lovejoy's saw-mill, a distance of 606 feet.*

Between Hennepin and Carver, if Hennepin's brink be placed at the foot of the undisturbed rock of Spirit island, the recession was about 412 feet.

These measurements were obtained by Prof. M. D. Rhame in 1876.



MISSISSIPPI RIVER AT ST. ANTHONY FALLS
SHOWING THE RECESSION FROM 1680 TO 1887.

Between Hennepin and 1856 the total recession amounts to 1,018 feet.

These give respectively the rates, 6.73, 4.79, and 5.08 feet per year, and for the corresponding periods necessary for the recession of the falls from Fort Snelling, 6,276 years, 8,819 years and 8,315 years. The average of these three results is 7,803 years.

These results are obtained by accepting the lining of a map constructed by general G. K. Warren for the United States government showing the distance from Fort Snelling, but it is not presumed that the distance is exactly eight miles, as assumed in these calculations. A recent estimate by Prof. W. R. Hoag makes the total distance eight and five-eighths miles.

The accompanying plan of the river at and below the falls (plate Y), showing by dotted lines the place of the falls at different dates, will be useful in illustration of the steps of this investigation.

Possible elements of error.

There are four considerations which may be mentioned as elements of doubt in the correctness of these results.

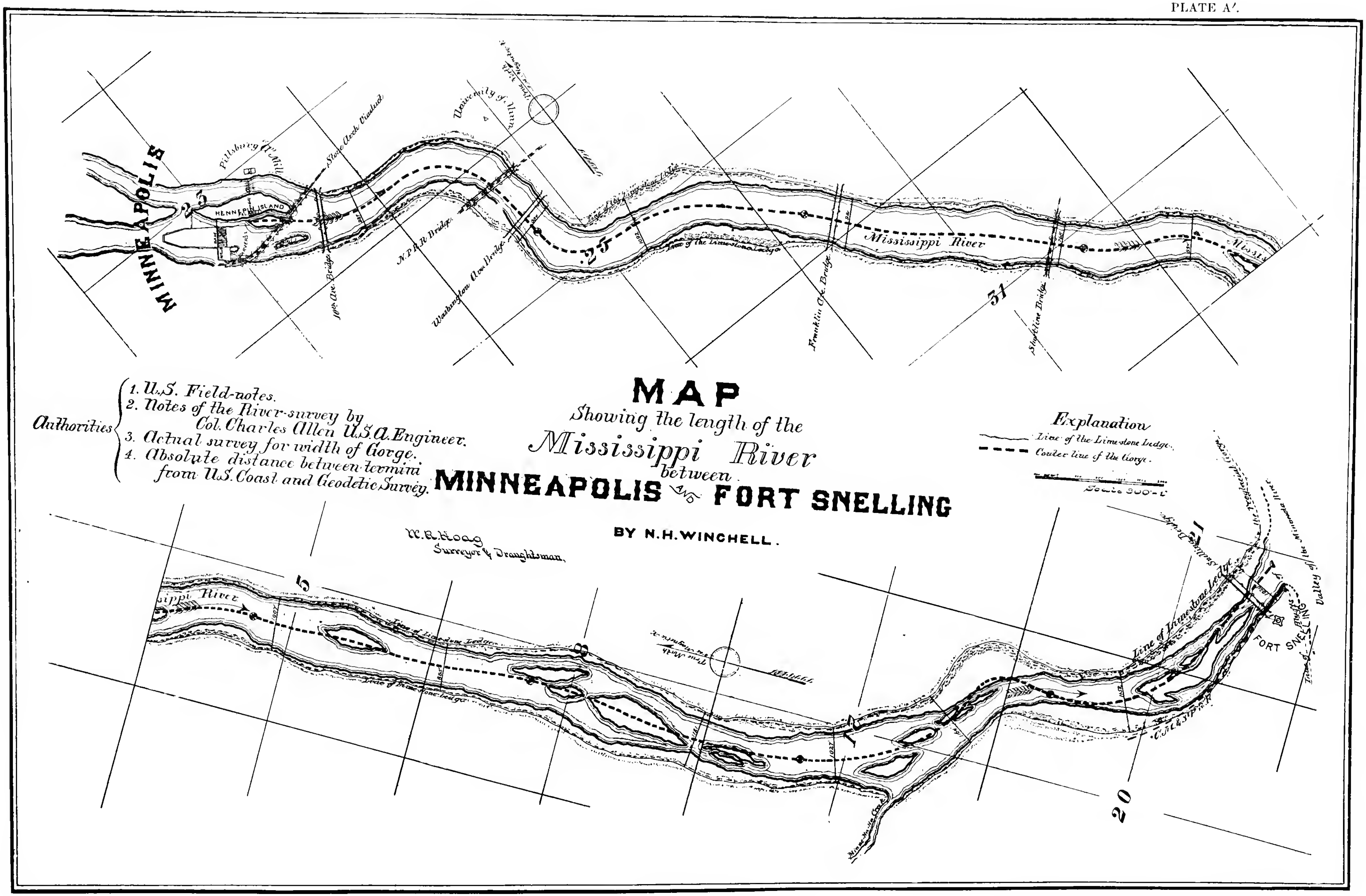
1. Difference of volume of the river.
2. Difference in the hight of the falls.
3. Uncertainty as to the place in the great drama of the glacial epoch where the recession began, whether at the beginning, at the acme of cold, or near its close.
4. As to the actual distance from Fort Snelling.

(1.) *Difference in the volume of the river.* There is indisputable evidence that the river was once immensely larger than it is now. It spread over the country in a vast lake-like Amazonian expanse, extending from the drift bluffs west of lake Calhoun eastward to the high bluffs in the eastern part of the city. It occupied this wide valley regularly and continuously. Whatever fluctuations it suffered from the seasonal changes through the year were not sufficient to cause it to withdraw within much narrower limits. At this time its water level, where it united with the Minnesota, rose above the bluffs at Fort Snelling. The Minnesota was likewise swollen. The same evidences for a former high-water stage in the Mississippi are seen along the valley of the Minnesota. A wide expanse of alluvial sand covers the high plains west of Fort Snelling, as already noted, nearly as far as Richfield.

With respect to the glacial epoch which is under consideration, when did this high water prevail, and how long did it continue? In the light of results attained within the last twenty years by the study of the drift deposits of North America, it is no novel assertion to state that *this high stage was due to the existence of the ice of the glacial epoch within the area drained by the upper courses of the Mississippi, and that it continued until the time that the ice had so far retreated that the waters discharged by it were able to reach the ocean by some other channel.* It is evident that while this high stage of the water continued there could have been no water-fall at Fort Snelling although the two streams united there. The valleys were both filled with water above the limerock rim. There is reason to believe that the volume of the Mississippi was reduced to its modern stage before that of the Minnesota. The Minnesota river drained the valley of the Red river of the North for a long period after the area of the state was freed from glacier ice. But even at this time there could have been no water-fall at Fort Snelling since the slow-flowing Minnesota would have risen nearly or quite as high at Fort Snelling, and the Mississippi's water would have entered a bayou-like mouth at the same level. As, however, the shrinkage of the Minnesota gradually uncovered the limerock, the Mississippi began to plunge over it to reach the level of the water in the great valley. When the Minnesota valley was finally relieved of the drainage from lake Agassiz the falls of St. Anthony may be said to have fairly entered upon the uniform recession which has above been considered.

It may be supposed perhaps that this flood-stage characterized these rivers during the slow on-coming of the ice of the glacial epoch, and also that during the actual existence of the cold epoch in its intensity the Mississippi was swollen to even greater dimensions. But these considerations do not have any bearing on this gorge. It has already been stated that the Mississippi's waters reached the valley of the Minnesota by way of another gorge now filled, between Bassett's creek and some point above Fort Snelling lying to the west of the present gorge until the morainic accumulations of the margin of the ice choked it so that it was compelled to seek another passage. The Mississippi did not occupy its present channel, and therefore could not have begun to excavate the rock-gorge until after the acme of cold of the last glacial epoch.

Again, as to the volume of water discharged by the ice at the time of


MAP
Showing the length of the
Mississippi River
between
MINNEAPOLIS AND FORT SNELLING
BY N.H. WINCHELL.
Authorities
1. U.S. Field-notes.
2. Notes of the River-survey by Col. Charles Allen U.S.A. Engineer.
3. Actual survey for width of Gorge.
4. Absolute distance between termini from U.S. Coast and Geodetic Survey.
Explanation
Line of the Limestone Ledge.
Center line of the Gorge.
W. R. Hoag
Surveyor & Draughtsman.
MINNEAPOLIS
HENNEPIN ISLAND
Pillsbury A Mill
Stone Arch Viaduct
University of Minn.
10th Ave. Bridge
N.P.R.R. Bridge
Washington Ave. Bridge
Mississippi River
Franklin Av. Bridge
Line of the Limestone Ledge
FORT SNELLING
Minnehaha Creek
Valley of the Minnesota River
Line of Limestone Ledge
25
31
5
8
17
20
21

greatest extent of the ice. It is admitted that the streams were all maintained at greater stage by the abundant waters discharged from the ice, and greatest at the acme of cold. But it is evident that before this water can swell any stream it must have a gathering area. Many streams, all swollen, must unite in order to swell the Mississippi at Fort Snelling. The waters escaped from the margin of the ice. As the margin widened, and was brought nearer the latitude of Fort Snelling, the drainage area which found outlet by this valley was narrowed. The Mississippi at lower points had its greatest volume when at Fort Snelling it had shrunken to its least. The margin of the ice was brought to this very latitude; and at that time only that water which *flowed directly from the ice at this point*, was found in the Mississippi valley. All the wastage that went on over the ice-field further north and northwest found drainage to the Mississippi through valleys that are tributary to it at points further south.

(2.) *Difference in the hight of the falls.* The falls were higher when at Fort Snelling than at any time since. The top of the limerock at Fort Snelling,* which probably was the brink from which the water was precipitated, is about 100 feet above low water in the Minnesota river. At the Lake street bridge it is 77 (?) feet above low water in the Mississippi. At the bridge of the Chicago, Milwaukee and St. Paul railway it is 79 feet. At the Franklin avenue bridge it is 76 feet. At the Northern Pacific railway bridge it is 55 feet. At the Tenth avenue bridge it is 43 feet, and at the upper end of the stone arch bridge of the St. Paul, Minneapolis and Manitoba railway it is 37 feet, making a difference between the falls at Fort Snelling and at the present time of 75 feet. Throughout this distance the dip of the limestone amounts to fifteen feet, up stream. If this be deducted there will remain 60 feet—which expresses the gradual filling up of the gorge by debris which the river failed to remove as the falls receded from Fort Snelling to their present position. The gorge is not a square-cut parallelogram exactly, eight miles long, but its upper and lower sides approach each other. The upper one descends fifteen feet and the lower one ascends sixty feet.

Other things being equal, it is probable that a simple increase in the hight of the falls would retard their recession, since it would remove the point of impact and friction occasioned by the falling water further from the brink of

* The firm building-stone beds.

the falls, and thus allow the retention of a body of the easily crumbled sandrock close under the limestone stratum so as to afford it a longer support. It requires, however, but a glance at the daguerreotypes of Mr. Hesler, confirmed as they are, by the description of the falls by travelers, particularly by the description of Prof. Keating, to discover that the hight of the falls has very little to do with the rate and manner of recession. It is not so much the excavation at the foot of the falls that causes the recession, as the excavation of the sandstone just below the limerock by water that enters natural joints of the rock and comes in contact with the crumbling sandrock, causing the dislodgement and final downthrow of large blocks. This operation is not affected by variations in the hight of the cataract, and hence the force of this supposed element of doubt is reduced to a minimum if not entirely negatived.

(3.) *When in the glacial epoch did the falls begin?* This point has already been considered in discussing the possible variations in the volume of the river. It is probable that the Mississippi, in diminutive form, began to flow in its new channel at the acme of the cold, since the moraine of the second glacial epoch runs across the country approximately through this region, and since it would have remained in its preglacial channel till it was driven out by the encroaching moraine. It was the easier removed from its old channel by reason of its reduction in volume. When it began its course in its new channel it flowed over a broad plain of gravel and sand, the then latest accumulations of glacial torrents. This plain of gravel and sand extended throughout the adjoining space now occupied by such drift deposits. The same kind of deposits filled the whole Minnesota valley, from side to side, and rose as high as the plains back of Fort Snelling. The river being comparatively small, had but little effect on these deposits. If it excavated any channel, the torrents from the ever-present glacier-ice filled them at once—indeed *it* excavated, *it* refilled, as *it* was glacier-born. It was on the retirement of the ice, bringing a greater drainage area into contribution to swell the main streams at this latitude, that these rivers began to deposit the fine loam-sand which covers the coarse gravel and sand of these terraces. It was still later, when the rivers were shrunken, by the partial or complete withdrawal of the glaciers from their remote sources, that they began to excavate through the loam and the gravel and sand, and finally entered on the slow erosion of rock gorges. Thus it appears that the date from which the recession of the falls must be reckoned was after the outlet of lake Agassiz had been opened toward the north, one of the last acts of the ice-age.

(4.) *As to the actual distance from Fort Snelling.* It has not been possible to obtain any exact measurement of the distance from Fort Snelling. But it is probable that the distance is slightly in excess of that which has been assumed.

Finally, if all the supposed irregularities be allowed their full force, and all the elements of doubt be admitted, their combined effect would not, at the most, more than slightly modify the result. And even if it should double the first result, or should reduce it to one-half, the chief value of the calculation is not impaired. That consists in showing the lateness of the last glacial epoch compared with the enormous time that has sometimes been supposed to have elapsed since its departure.

If the occurrence of our winter in aphelion, caused by the precession of the equinoxes and the revolution of the line of the apsides, about 11,300 years ago, was the cause of our last glacial period, it follows that it required about three thousand five hundred years for the withdrawal of the ice margin from the vicinity of Fort Snelling to that place where the discharge of lake Agassiz was opened toward the north, reducing the Minnesota to nearly its present size. This change must have given prominence and erosive effect to the water-fall at Fort Snelling, if it did not give it birth.

MATERIAL RESOURCES.

Fuel. There is a large annual cut of cord-wood from the timbered portions of Hennepin county, which finds market at Minneapolis and St. Paul. This comprises sugar maple, iron wood, oak, bass, elm and soft maple. The price per cord varies with the stringency of the money market. During the past year hard wood has brought five and six dollars per cord. Osseo is an important primary wood-mart; but large quantities are hauled by the first owners directly into Minneapolis. The county is generally heavily wooded, the thinly wooded and prairie portions being along the valleys of the Mississippi and Minnesota rivers, in the southeastern portion.

Building stone. Quarries are opened in the bluffs of the river on both sides. These are the most numerous on the west side below the falls. The stone furnished is extensively used for walls below the surface, and for foundations; but though formerly put in walls above the surface, its use in such positions has been abandoned whenever it is likely to be exposed to the elements. It is used as filling and backing in the interior walls. The reader is referred to the chapter in volume one of this report for information concerning the quality of this building stone.

In the upper part of the city, along the bluffs of the old river, as in the quarries opposite Boom island, and on the county line of Anoka county, this rock is very different, to a considerable depth, from that taken out below the falls. It shows the effects of very long weathering, probably dating from preglacial times. These differences are all accounted for by the known effect of water and iron, with the aid of time, on the shale with which the Lower Trenton is permeated. The thin sheets of shale which appear as dark belts of irregular and crooked direction on the newly-cut face of a "dimension stone," begin to decompose after the lapse of a number of years, causing a shattering and splitting of the whole mass. When the change takes place under the surface of the earth, but where the natural surface waters get free access, the iron that always accompanies such water, aided by the pyrites of the rock itself, gives a rusty and dirty, or yellowish color to the rock to a considerable depth. This is marked sometimes by the slow decomposition of the limestone itself, and by the sprinkling of sand or loam that covers the rock. In the face of these changes it is no wonder that a great many who have not watched them closely should be firmly persuaded that the different aspects could not be assumed by the same rock.

Brick clay. The clay which lies in the old river valley above the mouth of Bassett's creek is used, on both sides of the river for making brick. Formerly a small pottery establishment was run in the upper part of St. Anthony, using this clay, the product being light-colored but not always cream-colored.

Brick made from this clay is cream-colored; except, if poorly burnt, the topmost tiers of the kiln have a reddish color. Extensive manufactories are above the mouth of Shingle creek; those once located in the valley of Bassett's creek having been crowded out by the growth of other more important industries.

Lime. No quicklime is made from the Trenton limestone in Hennepin county, although a kiln was once run by Mr. Folsom, just below the falls on the east side.

Levi Guia burns lime from boulders at Dayton. His kiln has been erected eleven years, and is emptied sometimes to the number of six times per year.

Water-power. That which sustains the greatest industry, and furnishes the greatest revenue in Hennepin county, next to that of agriculture, is the water-power of the falls of St. Anthony. It is this that has given Minneapolis the pre-eminence of being the greatest manufacturing centre of the Northwest. The average volume of water passing over the falls is estimated at 35,000 horse-power at low water. Most of it can be used by means of the various improvements that have been made, diverting the water from above the falls into canals along the bank below the falls. The extensive flour-mills at Minneapolis, mainly run by this water-power, produced, in 1886, 6,168,000 barrels of flour, and 200,000 tons of millstuff. This was produced from 27,728,000 bushels of wheat, the total amount of wheat that was handled in the elevators of the city having been 34,904,260 bushels. The flour sent abroad direct from Minneapolis in 1886, was nearly one-third of the total flour-export from the United States for that year. The saw-mills at Minneapolis are mainly run by steam, and are situated above the falls. Their lumber-cut for 1886 amounted to 262,636,019 feet. The daily capacity of the twenty-four flouring mills is 35,000 barrels. The *Pillsbury A* mill is the largest in the world.

Outside of Minneapolis there were, in 1876, the following mills in operation in Hennepin county:

Pratt and Baird, Richfield, on Minnehaha creek, power produced by a dam; custom and shipping mill; four runs of stone; seven feet head.

Edina mills, also known as the *Red mills;* dam in Minnehaha creek; thirteen feet head; four runs of stone.

Metz and Peacka, below Minnehaha falls; power by a dam in Minnehaha creek; eleven feet head; two runs of stone; custom.

Baxter and Northway, Champlin; *Champlin mills;* two runs of stone; Elm creek power; fall sixteen feet; shipping and custom.

Weitzel and Hurlbut, Dayton; *Dayton mills;* Crow river power; fall nine feet; five runs of stone; ships at Itasca.

Henry Weitzel, sec. 10, Maple Grove; *Maple Grove mills;* Elm creek power; twelve feet fall; two runs of stone; custom.

McAfee and Company, N. W. ¼ sec. 21, Bloomington; *Bloomington mills;* twenty-six feet head; three runs of stone.

Balm Brothers, sec. 26, Eden Prairie; *Eden Prairie mills;* two runs of stone.

Minnetonka Mill Company, Minnetonka City; *Minnetonka mills;* dam in Minnetonka creek; twelve feet head; seven runs of stone; shipping.

Herrick, Douglas and Company, on Minnehaha creek; *Globe mills;* eight feet head; four runs of stone; shipping.

The woolen factory at Greenwood, on the Crow river, is owned by George Florida. It has one 52-inch Houston wheel, with 15 horse-power. The product of this mill is sent throughout the Northwest, and specially to Dakota.

The flouring mill at Rockford, immediately across the Crow river from Greenwood, is also owned by George Florida. It has four sets of double rollers, 7½ feet head of water, and has a capacity of 75 barrels per day. Its power is distributed by three wheels, viz.: One old 60-inch American, one 60-inch Jonval, and one 6-inch La Croix, making together 75 horse-power. It has also one run of stone for feed.

Another small mill owned by Mr. Florida, has a 36-inch wheel, with 15 horse-power.

There is a mill at Hanover, six miles below Greenwood, having flour, feed and sawing machinery, owned by Volbrecht Bros.

EARTHWORKS.

There are numerous artificial earthworks in Hennepin county. But little has been done to study or even to ascertain the location, form and size of these mounds. As the work progressed in making the geological survey, nothing could be done more than to note their existence, with the following results:

There are a great many along the Minnesota river, above Fort Snelling; two or three on sec. 1, Bloomington; one is on the road near Mr. Van Ness', near the line between sections 1 and 12, Bloomington. They occur on Mr. Brusseau's land, sec. 14, and frequently along the bluff further up, as far as Shakopee, at least.

There is a large mound on sec. 27, Eden Prairie, visible for some distance across the prairie.

There is a mound on S. E. ¼ of sec. 1, Minnetonka, near Wayzata.

At Mound City, at the western end of lake Minnetonka are "about 40" mounds on sec. 24, Minnetrista. A number of others are on Nobles island, near the same place; others are on N. Saunders' farm near Halstead's bay, sec. 22. There are others at Excelsior, on P. M. Gideon's land, sec. 28.

On the land of James Shaver, N. W. ¼ sec. 17, Minnetonka, are a great many mounds. In the summer of 1875 a number of these were located by chain and compass by a party from the Minnesota Academy of Sciences. They were found to lie on the bluff and knolls overlooking the water of the lake, following the higher land, without regard to direction or relative position. No plan or order was discernible, though about twenty were carefully surveyed. They vary in hight from two or three feet to five or six, and from ten feet in diameter to forty. There are in that neighborhood fifty or more within the area of a quarter-section of land.

Eight mounds of the same kind are seen on widow Ferguson's land, sec. 23, Excelsior, also overlooking the lake. Others are on N. W. ¼ sec. 11, Medina, land of Albert Johnson; and on Samuel Barto's, sec. 7, Minnetonka; a large one is on the first high point east of Gale's island on Big island.

Some at Palmer's lake have been opened by members of the Minnesota Academy of Natural Sciences, and their contents described by Dr. A. E. Johnson. A fine specimen of a platychnemic shinbone, considered by him to be characteristic of the mound-builders, was taken from a mound at Palmer lake.

There are two large mounds on the south bank of Crow river, at Dayton, forty feet across and about ten feet in hight.

Four are on Aaron Hoag's land, sec. 18, Hassan.

There is another large mound on James Ream's land, two miles above Dayton, on the north side of the Crow river.

Two artificial mounds are on the north shore of Crystal lake, originally 4–6 feet high, but one has been dug into at the top and now is but 3 feet high.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

RAMSEY COUNTY

BY N. H. WINCHELL

Explanation.

- *Rolling or hilly Till*
- *Flat or undulating Till*
- *Fine flat clay more or less laminated*
- *Terrace gravel and sand*
- *Alluvium.*
- *Trenton Limestone*
- *St. Peter Sandstone*

Contour Lines *are drawn approximately for each 50 feet above the sea.*

Julius Bien & Co lith

CHAPTER XII.

THE GEOLOGY OF RAMSEY COUNTY.

BY N. H. WINCHELL.

Situation and area. With the exception of a part of the city of St. Paul, Ramsey county lies on the east side of the Mississippi river, and below the mouth of the Minnesota river. It is situated between Anoka and Hennepin counties on the west and Washington on the east. It is the smallest county in the state, but embraces St. Paul, the capital. Its area is 187.15 square miles, of which 13.45 square miles are covered by water. The equivalent acres are 119,774.05 and 8,605.34. The southern boundary is formed by the Mississippi river from a few miles below the falls of St. Anthony to six miles below the Union depot at St. Paul where the Washington county line abruptly turns west to the river. Within this distance the Mississippi gorge makes two great bends, one at the mouth of the Minnesota where it unites with the preglacial gorge of that stream and the other at St. Paul where it takes again its normal, more southerly, course. Its winding direction forms, on the southern border of the county, a large letter S supine. This river is navigable to St. Paul, and smaller craft run to Fort Snelling and thence up the Minnesota. Above Fort Snelling the Mississippi is rather rapid, and is obstructed by alluvial islands, or by rocky debris left by the recession of the falls of St. Anthony. Plate 43 represents Ramsey county.*

SURFACE FEATURES.

Natural drainage. The Mississippi is the great avenue toward which all the waters of the county tend, and which they finally reach. The northern

* The Union depot at St. Paul should be represented on this plate about half a mile further west. The line of the Chicago, Burlington and Northern railroad should be shown running southeastward from St. Paul, nearly parallel with the Chicago, Milwaukee and St. Paul railroad.

part of the county, however, has an immediate drainage northwestwardly, by way of Rice creek, and its surface waters enter the Mississippi about seven miles above the falls of St. Anthony. This stream gathers the overflow from several lakes, and seems to receive also the under-surface drainage from several others, and maintains a steady discharge-volume even through the summer season. White Bear and Bald Eagle lakes discharge into a tributary of Rice creek which takes a northern circuit through Anoka county, by way of Centerville, returning again through Mound View township. The upper sources of Phalen's creek, which joins the Mississippi at St. Paul, are in McCarron, Phalen, Gervais, Fitzhugh and other lakes, which supply St. Paul with city water through viaducts that have been constructed diverting it from its natural course to the Mississippi.*

The southern part of the county, mainly occupied by the Trenton formation, is generally higher than the northern. The drainage courses which pass through it toward the Mississippi, lie in deep valleys which are surrounded and hid by hills and ridges of drift. These hills probably are due primarily to a rock-sculpture older than the drift, but the drift is so thick that the rock seldom appears in exposure above the surface. There is some appearance of the former extension of the valley of Rice creek much further southward, and it is no unreasonable suggestion that the great Mississippi itself may have once occupied this valley, entering the great gorge at St. Paul and meeting there the waters of the Minnesota.

Topography. A low water-shed crosses the county east and west through the central portion, the average hight of which is about 950 feet above the sea. But toward the southwestern part of this divide, in the vicinity of the experimental farm of the state university, it reaches the hight of over one thousand feet. The higher portions of this divide are known to be underlain by the outrunning northern edge of the Trenton limestone, while the lower levels, and the area occupied by the numerous lakes that lie a few miles further north, are probably situated on the St. Peter sandstone and the underlying magnesian limestones. These lower rocks, however, are entirely concealed by drift deposits of which Ramsey county received a very generous supply and which present a diversified and very interesting character. Flanking this divide on the

* The lakes connected for this purpose are reported to be Vadnais, Wilkinson, Deep, Long, Charley, Pleasant, Lambert, Otter and Bass, but some of these names evidently are lately applied to lakes that have been known otherwise.

east and west, two other prominent topographic features are noticeable. These diverge from the city of St. Paul. They appear as elevated plateaus, and rise as high as the divide itself, thus embracing, in a rudely triangular form, a tract that, while lying from fifty to a hundred and fifty feet lower, yet presents a rolling surface and finds a drainage-outlet into an ancient bayou of the pre-glacial Mississippi at the point where the railroads from the north approach the river. The valley of Phalen's creek is included in this triangular area. The plateau which bounds it on the west begins at St. Anthony hill and runs to the experimental farm and northwestwardly into Hennepin county; that on the east begins at Dayton's bluff just east of the mouth of Phalen's creek, and extends northeastwardly to Castle, near Silver lake. This elevated land is probably due, primarily, to the preservation of the Trenton limestone, but it is considerably influenced by a copious deposition of morainic drift.

North of the east-and-west water-shed is another marked topographic feature. Here is the highest part of the county. In the central portion of Mound View a prominent ridge of drift, consisting mainly of gray till, extends north and south about three miles. It is rolling, and massive, and its highest knobs reach about 1100 feet above the sea. Toward the south it sinks away gradually into the prevailing rolling tract which occupies the central part of the county. Toward the north it ceases abruptly. Its northern extension, on the east, west and north, is surrounded by flat, or slightly undulating land that lies two hundred feet lower than the highest knobs. This flat surface extends eastward to the large lakes in White Bear, and surrounds them. It also characterizes a considerable tract in Washington and Chisago counties, extending northward from White Bear lake.

With unimportant exceptions the northern third portion of the county is flat, while the remainder is rolling or hilly, becoming more and more broken toward the Mississippi. This rolling surface in the southern portion is due to the *posé* of the drift materials, and not to any upheaval in the rocks, which lie everywhere practically horizontal. The strata, however, had been eroded by streams prior to the drift epoch, and were crossed by deep gorges. This uneven surface materially modified the manner of deposition of the drift and determined its composition at special points. Thus, the drift materials seem to have been accompanied by turbulent waters in the southern portion and by quiet waters in the northern portion of the county. The drift surface, therefore, in the northern part is characterized by moderate contour changes, the rather shallow lakes in many instances not being situated in deep valleys but frequently skirted by extensive marshes or "hay meadows," which rise gently into the surrounding upland. The soil is a sandy loam and the subsoil a laminated, or finely pebbly clay. On the other hand the lakes that lie further south are in deep basins, having gravelly shores, and frequently attractive natural surroundings. The soil is more stony, and large boulders are common, while the railroad cuts disclose a subsoil either of coarse gravel or of red and stony till.

Description of the towns of Ramsey county.

TOWN **30** N. **23,** W. MOUND VIEW. The hills already described, near the centre of this town, give it its name. Aside from these hills, and a tract along the southwest corner, the whole town is flat or gently undulating, and has a rather sandy soil. This sand, however, is closely underlain by an impervious clay, as evinced by the numerous lakes and marshes which are found within its limits. Rice creek is a slow crooked stream, frequently bordered by marshes or hay meadows. The town is somewhat more than half covered with small oaks, with aspens and elms in the low grounds.

TOWN **30** N. **22,** W. WHITE BEAR. The northern and central parts of this town are flat. It has throughout a light, often sandy, soil. But on the more elevated portions, in secs. 31–36, where some outlying remnants of the Trenton limestone give the well-known mound-outline to the hills, the surface is more clayey, and the timber is more robust. There is a group of low hills, somewhat morainic, in secs. 5 and 8, east of Pleasant lake, and in the southeastern part of sec. 36, the strike of the Trenton limestone gives a sudden elevation to the general upland from 150 to 175 feet above the level of the flat land adjoining toward the north and northwest. The subsoil is a gravelly clay, which sometimes rises so as to form also the soil; but the surface soil usually is either a sandy loam, which sometimes becomes too light for good farming, or is clay with a flat surface.

TOWN **29** N. **23,** W. ROSE, *and the northwest part of* ST. PAUL (*partly in Hennepin county*). The southern part of this town is high and rolling, with a red clay subsoil. The northern and northeastern part is undulating, sometimes flat, and has a sandy soil. This is specially the case in the vicinity of lakes Josephine, Big Bass and McCarron. Lake Como is in the southeastern part of this town. Secs. 16, 17, 21 and 22 are mainly of prairie. The rest of the town is well timbered.

TOWN **29** N. **22,** W. NEW CANADA, *northeast part of* ST. PAUL, *and north part of* MCLEAN. This town embraces a great variety of topography. The eastern part is elevated about two hundred feet above the central. In some places on this plateau the surface is nearly flat, but in general it is rolling. This plateau is about two miles wide. It descends toward the east in Washington county and exhibits, on both flanks, a rolling, often stony, morainic drift aspect. Yet its greater elevation is supposed to be due to the preservation of the Trenton limestone, extending in a spur northeastwardly from Dayton's bluff at St. Paul. The central portion is much broken with some outliers of the Trenton in the form of mounds, and with lakes that constitute the uppermost sources of Phalen's creek. A morainic covering of drift also spreads over this town, from which the immense quantities of gravel and sand have been derived which are found in the lower ridges and terraces.

TOWN **28** N. **23,** W. RESERVE, *and west part of* ST. PAUL. (*Partly in* HENNEPIN *and* DAKOTA *counties*). In the uplands this town has a rolling and generally a gravelly clay surface. Along its southern border is the Mississippi valley, and a flat, or series of flats, generally wet on account of perennial springs that are caused by the closely underlying Trenton shales. These shales, however, are more or less covered by the high gravel-terrace that borders the Mississippi. The town is thinly clothed with a forest of oaks and aspens, or is a rolling prairie. It contains no lakes and but few marshes. At the N. E. corner of sec. 16 is a conspicuous promontory, 975 feet above the sea, from which is visible an extensive landscape. Hamline and Macalester colleges, the university of Minnesota, the hills in Mound View, the buildings on the experimental farm, the state fair grounds, the plateau in the eastern portion of New Canada, the cities of Minneapolis and St. Paul, the winding course of the lower reach of the Minnesota river, with its rounded drift-banks, the broad Mississippi valley below St. Paul, Pilot Knob in Dakota county, and the more elevated hills further east, Fort Snelling, Minnehaha falls, Mendota, where the capital of the state was first fixed by senator Douglas in the enabling act,*— these are visible and are "within the radius" in which Mr. Seward prophesied the future capital of ultimate America.

TOWN **28** N. **22,** W. McLEAN, *and the east part of* ST. PAUL. (*Partly in* DAKOTA *and* WASHINGTON *counties*). This town shows the same extremes as Reserve, but they are more marked. The bluff portion, east of the Mississippi, is about a mile and a half wide, and three miles long, running north and south, and is cut by east and west valleys and by tributary creeks so as to have a rough or hilly surface. It is considerably more than half covered with small timber (oaks and aspens). The rest of this town, east of the river, is alluvial, and is occupied by hay-meadows or is a wet marsh. A belt of soft timber, growing to large dimensions, separates it from the river-channel. On the west side of the river there is a repetition of these features, but in reverse order, included within the limits of West St. Paul.

Elevations. The highest points in the county rise about 1100 feet above the sea, being the northerly of the hills in Mound View. The low-water level of the Mississippi at St. Paul is 685 feet; and at the southern limit of the county it may be fifteen feet lower. The city datum of the engineer's levels for the city of St. Paul is 693.

Average elevation of Ramsey county. The various railroads that cross Ramsey county furnish a basis for the contour lines seen on the accompanying map of the county (plate 43), and for estimating approximately the elevation of the various towns, viz.: Mound View, 900 feet above average tide; White Bear, 880; Rose, 920; New Canada, 960; Reserve, 850; St. Paul, 810; McLean, 815. These give, when calculated according to their different sizes, an average elevation for the county, of 895 feet.

Elevations on the Chicago, Milwaukee and St. Paul railway.

From profiles in the office of M. D. Rhame, engineer, Minneapolis.

	Miles from St. Paul Union depot.	Feet above the sea.
Hennepin county line, N. W. ¼ sec. 32, Rose, -	7	849.66
Ford's nursery,	6.6	874.66
Merriam Park,	5.8	909.66
Summit (Snelling avenue),	4.8	938.66
Under Summit avenue, -	4	908.66
Big cut, natural surface 929.66, centre,	3.8	901.66
St. Clair street,	3.5	876.66
Grace street,	2.8	829.66
Fort street,		789
Chestnut street,	.8	710.41
Union depot, St. Paul,	0.0	704
Dayton's bluff,	1	709
Newport,	8	751
Mendota Junction,	5.5	721

* See *Collections of the Minnesota Historical Society.* Vol. iv. p. 204.

Minnesota and Northwestern railway.

From profiles in the office of H. Fernstrom, St. Paul.

	Miles from St. Paul Union depot.	Feet above the sea.
St. Paul,	0.0	704
Bridge over the Mississippi river,	.1	712
West St. Paul,	.8	704

St. Paul and Northern Pacific railway.

From profiles in the office of chief engineer J. W. Kendrick, Minneapolis.

	Miles from St. Paul Union depot.	Feet above the sea.
Small iron bridge, near Fourth street, St. Paul,		716.86
East Seventh street,		726.64
Trout brook, water 737.64	1	747.64
Westminster street,		752.64
Crossing of the Manitoba railroad (in tunnel),		757.64
Crossing of the Chicago, St. Paul, Minneapolis and Omaha railroad,		762.14
Trout brook crossing, second time, water 765.64,	1.4	768.64
Mississippi street,	1.6	784.47
Trout brook, water 790.64, public road 792.64,	2.1	798.64
Cortland street (cut 30 feet),	2.4	817.64
Rice street station,		837.64
Crossing of creek,	3.5	856.64
Western avenue,	3.6	858.64
Dale street,	4.3	889.64
Como avenue,	4.6	911.49
Como road,	4.7	912.14
Section line between 27 and 26,	5.2	925.64
Warrendale,		925.41
Summit on the Como property,	5.6	977.84
Snelling avenue (Hamline),	6.2	922.44
Cut of 20 feet,	6.4	912.64
Track to the State Fair grounds,	6.5	909.64
Westwood avenue (fill 13 feet),	6.8	899.64
Section line between secs. 29 and 28, on Rich avenue,	7.3	898.64
Raymond avenue,	7.6	902.64
Bayless avenue,	7.7	903.64
Transfer track, St. Paul, Minneapolis and Manitoba railway,	7.9	902.24
St. Anthony Park,		904.64
County line crossing, in St. Anthony Park,	8.4	885.64
Prospect Park,		869
University avenue,	9.4	827.64

Chicago, St. Paul, Minneapolis and Omaha railway.

From Edward Johnson, chief engineer.

	Feet above the sea.
St. Paul, east end of Union depot sheds,	708
St. Paul, Junction with the St. Paul, Minneapolis and Manitoba, near East St. Paul,	780
East St. Paul,	827
Midvale,	1012
Mendota depot (Chicago, Milwaukee and St. Paul railway, 737),	722

Chicago, Burlington and Northern railway.

	Miles from St. Paul Union depot.	Feet above the sea.
Pig's Eye bridge,	2	707.5
Newport,	7.5	749.8

St. Paul and Duluth railway.

From profiles in the office of H. A. Swenson, St. Paul.

	Miles from St Paul Union depot.	Feet above the sea.
St. Paul, Union depot,	0.0	704
Crossing of the Chicago, St. Paul, Minneapolis and Omaha railway (20 feet above this grade),	2.1	806
Phalen's creek (water 802),	2.1	808
Phalen's creek (water 806),	2.2	810
Phalen's creek (water 813),	2.4	817
Phalen's creek (water 836),	3.1	850
Claymont (at St. Paul Harvester Works),	3.4	874
Phalen's creek (water 853),	3.6	865
Summit (cutting 11 feet),	9.4	965
Minneapolis and St. Louis railway junction,	10.6	924
White Bear,	11.9	935
Junction for Stillwater,	12.1	935
Bald Eagle,	13.1	924
Beaver creek (water 923),	16.9	932
Centreville,	17.2	932
Hennepin-Ramsey county line, near St. Anthony (cut 7 feet),		945
Half mile west of Robinson's lake (cut 16 feet),		920
Robinson's lake, S. E. ¼ of sec. 4, Rose (water, 905 feet),		913
Summit one-third mile east of Robinson's lake (cut 7 feet),		924
Bennett lake (water 890),		892
Clay ridge, eight hundred feet further east (cut 20 feet),		895
Cut, on sec. 1, Rose (cut 18 feet),		904
Big Bass lake (water 885),		895
Tamarack swamp, east of Big Bass lake,		890
[This swamp seemed to consist of a mass of floating peat, grass-roots, etc., supporting small tamarack trees. Three piles were driven (spliced), each 60 feet long, making 180 feet, without reaching solid foundation. The track was then supported on a raft consisting of logs, slabs and brush thrown on the surface.]		
White Bear flats,		930
Junction at White Bear,		924

Wisconsin Central line.

Furnished by F. W. Fratt.

	Feet above the sea.
Junction with St. Paul and Duluth railroad, Gladstone,	938
Castle, on the Washington county line,	1025

St. Paul, Minneapolis and Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, St. Paul.

	Miles from St. Paul Union depot.	Feet above the sea.
St. Paul Union depot,	0.0	704
Elevator B,		855
Rice street,		840.60

Como avenue, -		857.60
Summit between St. Paul and Minneapolis (cut 14 feet),	5	936
Hamline (university),		925.60
St. Anthony Park,		883.60
St. Anthony (East Minneapolis) Junction,		842

Miscellaneous elevations in Ramsey county.

	Feet above the sea.
Mississippi river at Pike island, ordinary low water,	688
Mississippi river at Pike island, high water,	710
Mississippi at St. Paul, ordinary low water,	685
Mississippi at St. Paul, extreme low water,	683
Mississippi at St. Paul, extreme high water,	702
Mississippi at Newport,	676
Lake Como,	885
Lake Phalen,	859
Magoffin's lake (sec. 18, New Canada),	874
Big Bass lake,	885
Vadnais lake,	879
"Clearwater lake" (St. Paul water works),	885
"Clear lake" (St. Paul water works),	889
Pleasant lake,	891
Bald Eagle lake,	908
White Bear lake,	920
Forest lake (Washington county),	900
Mound View hills, about	1100
Observatory hill, in Reserve, about	975
Bluffs back of the capitol, head of Robert street,	911
Summit avenue bluff,	920
St. Paul city datum,	693

Soil and timber. Taken altogether the soil of Ramsey county is rather sandy. This element prevails in those areas which are known to be closely underlain by the St. Peter sandstone, and in valleys which have been flooded by waters that carried the detritus of that rock for short distances and spread it over the clay and stony tills which were deposited by the drift agencies. The valley of Rice creek, in general, and its southeastward extension by way of Trout creek, and especially the land that intervenes between lakes Johanna and McCarron, constituting a kind of divide between those valleys, are examples of this sandy soil. This sandy loam is also spread over much of the north-central and the northeastern portions of the county, especially about White Bear and Bald Eagle lakes. This is the latest soil formed. It is spread along the valley of the Mississippi so liberally that it seems to constitute everywhere the general surface. It is seen in all the railroad cuts between St. Paul and Minneapolis, but in these cuts, and generally in the uplands, it exists because of its distribution by the latest of the high waters that accompanied the last ice-epoch. Mingled with it here also must be sand from the sandstone strata of the St. Croix and Potsdam that outcrop in counties further north.

This sandy surface soil is closely underlain by subsoils, in the lower levels, composed of coarser sand and gravel in some places, and of compact clay in others. These underlying drift deposits gradually become apparent as one travels from the valleys to the uplands—due to the thinning out of the sandy loam. On the hills they constitute the soils, being modified only by such variations and limitations as are due to long exposure under subaërial and vegetal influences, and the different action of the ice-period at different points. In the morainic portion of the county, which indeed embraces the larger part of the county, especially the central portions, when these older, and lower, deposits are uncovered, or are penetrated by excavations, they are found to be either red till, or the gravel and sand that were derived from the red till. Such knolls are common in New Canada and in the high lands in the eastern part of McLean, and in the eastern part of Rose. But toward the north, in much of White Bear and Mound View, and in the northwestern part of Rose, when the subsoil of the lowlands becomes the soil of the uplands it shows as a gray clay which is in some places a clayey loam, somewhat stratified, and in others is tenacious and impervious. Examples of this underlying stratified portion can be seen in the northern part of White Bear township, extending into Washington and Anoka counties, where the surface is generally flat. Examples of this clay with a rolling contour, and with a pebbly tendency, constituting the surface soils at higher levels, can be seen in the western part of Rose and Mound View and the northeast part of St. Anthony. This same gray clay seems to constitute the brick clays at Shingle Creek, in Hennepin county, and appears in patches, in the midst of stratified valley-drift, on the university campus and at St. Paul. A similar loam, probably of the same date and origin, but of a red color, covers the high lands in the southeastern part of the county, and appears along the bluffs in West St. Paul.

The three different, typical soils, viz: the sandy loam, the red till or its gravel and sand, and the stoneless clay, must be considered as types that mark the greatest divergence in the foundation or primary soils of the county. They are locally subject to great modifications incident to the prevalence of vegetation, the surface contour, the direction of the sloping surface, the impact of prevailing winds, the presence or absence of water in suitable amounts, and the ever varying relations which they sustain to each other. The surface transitions from one to the other are not generally abrupt, but owing to the long action of winds and drainage the materials from one are mingled with those of that adjacent, and the change from type to type is rendered gradual. Below the surface, however, wherever the contact can be seen, the transition is more abrupt, but its conditions and causes appertain properly to the description of the drift.

The forests of Ramsey county are not dense, but rather thin. The trees are small, generally, and although there is probably as great a variety of species, taking the whole county together, as can be found in this part of the state in any equal area, yet several of the species that in the Big Woods are scattered thickly through the forest and reach a large size, are, in Ramsey county, restricted to special areas, while a comparatively small number of species are spread at large over the county, giving a monotonous character and limited range to the general arboreal vegetation. In this respect Ramsey county is similar to the red-till-and-gravel areas of the southeastern part of Hennepin county, and the northern part of Dakota county. Black and bur oaks constitute the most of the native forest, but there are mingled with these, sometimes in large plains on which but few oaks can be seen, aspen and poplar groves. Tamarack is common in some of the large swamps in the northern parts of the county. The most valuable forests are found in the flat clay lands in the northern part of White Bear, extending northward into Anoka county, and northeastward into Washington.

The following species of trees and shrubs were noted growing native in the county:

Quercus coccinea, *Wang*, var. tinctoria, *Gray*. Black oak.

[This is by far the most abundant oak in the county, as it is throughout the southern half of the state; but there are some situations, particularly exposed, high hillsides, like the tops of the Mound View hills, in which it is noticed to fail, though growing abundantly on the lower levels, and to be replaced by bur oak. It does not frequently appear as a large tree, and is generally less than ten inches in diameter, or simply has the size of shrubs, intermixed with bur oaks of the same size.]

Quercus rubra, *L.* Red oak. Rare.

Quercus macrocarpa, *Michx.* Bur oak.

Quercus alba, *L.* White oak.

Ulmus Americana, *L.* (*Pl. Clayt.*) *Willd.* American elm.

Populus tremuloides, *Michx.* Aspen.

Populus grandidentata, *Michx.* Great-toothed poplar.

Populus monilifera, *Ait.* Cottonwood.

Tilia Americana, *L.* Basswood.

Negundo aceroides, *Mœnch.* Box-elder.
Juglans cinerea, *L.* Butternut.
Carya amara, *Nutt.* Bitternut.
Fraxinus Americana, *L.* White ash.
Fraxinus sambucifolia, *Lam.* Black ash.
Acer rubrum, *L.* Red maple.
Acer saccharinum, *Wang.* Sugar maple. Rare.
Betula papyracea, *Ait.* Paper or canoe birch.

[This grows about rocky banks of streams and lakes, sometimes becoming twelve and fourteen inches in diameter.]

Larix Americana, *Michx.* Tamarack.
Juniperus Virginiana, *L.* Red cedar.

[Large trees grow at lake Johanna and on the north shore of Turtle lake, and also along the rocky bluffs of the Mississippi.

Ulmus fulva, *Michx.* Slippery elm.
Prunus serotina, *Ehr.* Black cherry.
Pinus strobus, *L.* White pine.

[Only along the Mississippi above Fort Snelling. A single tree grows near Mahtomedi, on the east side of White Bear lake.]

Betula lutea, *Michx. f.* Yellow or gray birch.

[At lake Johanna.]

Prunus Pennsylvanica, *L.* Small red cherry.
Prunus Americana, *Marsh.* Wild plum.
Xanthoxylum Americanum, *Mill.* Prickly ash.
Ostrya Virginica, *Willd.* Ironwood.
Carpinus Americana, *Michx.* Water-beech.
Prunus Virginiana, *L.* Choke cherry.
Amelanchier Canadensis, *Torr. and Gray.* Juneberry.
Pyrus coronaria, *L.* American crab-apple.
Rubus occidentalis, *L.* Black-cap raspberry.
Rubus strigosus, *Michx.* Red raspberry.
Rubus villosus, *Ait.* High blackberry.
Ribes Cynosbati, *L.* Wild gooseberry.
Ribes rotundifolium (or gracile), *Michx.* Smooth wild gooseberry.
Ribes lacustre, *Poir.* (?) Swamp gooseberry.

[Has a smooth fruit in racemes.]

Sambucus Canadensis, *L.* Elderberry.
Spiræa opulifolia, *L.* Ninebark.
Spiræa salicifolia, *L.* Meadow-sweet.
Celtis occidentalis, *L.* Hackberry.
Alnus incana, *Willd.* Speckled alder.
Alnus serrulata, *Ait.* Smooth alder.

[On the flats north of White Bear lake.]

Amorpha canescens, *Nutt.* Lead plant.
Amorpha fruticosa, *L.* False indigo.
Rhus glabra, *L.* Smooth sumac.
Rhus typhina, *L.* Staghorn sumac.
Rhus Toxicodendron, *L.* Poison ivy.
Vitis cordifolia, *Michx.* Frost grape.
Symphoricarpus occidentalis, *R. Br.* Wolfberry.
Corylus Americana, *Walt.* Hazel.
Cornus sericea, Silky cornel. Kinnikinick.
Cornus alternifolia, *L.* Alternate-leaved cornel.
Cornus paniculata, *L'Her.* Panicled cornel.
Ceanothus Americanus, *L.* Jersey tea.
Vaccinium corymbosum, *L.* var. amœnum. Swamp blueberry.

Lonicera parviflora, *Lam.* Small honeysuckle.
Celastrus scandens, *L.* Bittersweet.
Ampelopsis quinquefolia, *Michx.* Virginia creeper.
Rosa blanda, *Ait.* Early wild rose.
Viburnum Opulus, *L.* High-bush cranberry.
Cornus stolonifera, *Michx.* Red-osier dogwood.
Cratægus coccinea, *L.* Thorn.
Salix nigra, *Marshall.* And other willows.

THE GEOLOGICAL STRUCTURE OF RAMSEY COUNTY.

The drift deposits conceal the indurated rocks from sight everywhere except along the immediate bluffs of the Mississippi river. Hence the colors representing the older formations found in Ramsey county—the Trenton limestone and the St. Peter sandstone—occupy but a small part of the map of the county (plate 43).

The Trenton shales and limestone. The limestone member of the Trenton is visible in the river bluffs along the whole southern border, and is frequently wrought for building-stone. The shales which overlie this stratum are visible at nearly all the quarries, but their full thickness is known only by examination along the ravines that cut across the bluffs, at levels above the quarries, and by the records of the deep well sunk at the state reform school, S. E. ¼ sec. 34, Rose. These shales and limestone, with a united thickness of about one hundred feet (138 feet at the reform school), extend northeastwardly and northwestwardly from St. Paul, and are the foundation rocks of the elevated plateaus on which are situated, in one direction, the village of Castle, on the Wisconsin Central railway, and in the other, the experimental farm and the adjoining high lands toward the northwest. The limestone also is known to exist in some of the mounds in the northern part of New Canada and the southern part of White Bear. But in the main it seems to have been destroyed in White Bear and Mound View, if it ever existed so far north, and in a central valley which contracts from the north and concentrates the drainage and erosive agencies, both past and present, upon the Mississippi at St. Paul.

The shales themselves embrace thin beds of very fossiliferous blue limestone, but about seven-ninths of the entire thickness, as found in the deep well at the reform school, consist of a soft, blue, calcareous shale which is easily converted to mud wherever it outcrops at the surface, and is then apt to acquire a greenish tint. This shale embraces a great many specimens of

Rhynchonella capax and *R. ainsliei*, *Orthis minneapolis*, *O. perveta*, *subequata*, *tricenaria* and *plicatella*, *Leptæna sericea*, *Zygospira* (n. sp), and of different bryozoans. On the fossiliferous slabs that become disintegrated from the shale are found not only many specimens of the same species as in the shale, but a great variety of fragile fossils that appear as incrusting attachments on their outer surfaces, with the most delicate tracery, and the plications and perforations of their structure most perfectly and beautifully preserved. Large orthoceratites also are found in the shale-bed which lies immediately above the main building-stone stratum. Small trilobites and species of *Crania* sometimes appear attached to the dislodged limestone slabs.

The limestone which is distinctively called *Trenton limestone*, in Ramsey county is separable into three parts which have pretty constant characters, viz.:

General section of the Trenton limestone.

1. Impure, harsh, drab or dirty-buff limestone, having a perceptible per cent of magnesia, containing lumps of calcite and numerous casts of fossils, specially of *Strophomena minnesotensis*, and *S. alternata*, *Orthis tricenaria*, *Cypricardites ventricosus*, *Murchisonia tricarinata*, and *M. ventricosa*, *Pleurotomaria subconica*, and species of *Bucania* and of *Bellerophon;* also some *Lingulæ* and small orthoceratites. 6 to 10 feet.

2. Shale and calcareous shale, with fragments of fossils, and sometimes a large orthoceras. 6 to 10 ft.

3. Limestone, with aluminous partings. This is the building stone of St. Paul. The mingling of shaly and calcareous parts throughout this limestone causes the dressed surfaces of large slabs to have a blotched or mottled shading of the darker and lighter tints of blue, particularly when the dressed side coincides with the natural bedding. This member is the most persistent of the Trenton, but splits into thin layers on long exposure, due to the loosening of the shale throughout the mass. This contains fossils characteristic of the Trenton but generally in a fragmentary condition. It is a common thing to see at any quarry in constant operation, sections of orthocerata or "petrified snakes" that have been thrown out by the workmen. Every visitor is entertained by descriptions of their great size, their enormous length and their positions in the bedded rock where they lay while the work of the quarry progressed. 15 feet.

Besides the three main parts above described there are also several thin beds of shale in No. 1 which seem not to be confined to any definite horizon, and nearly always a layer of green shale below No. 3.

In sections of the bluffs at St. Paul, given in Dr. Owen's final report, this limestone is represented as greatly broken and even faulted, along the river from Fort Snelling to St. Paul, and especially in the vicinity of the *new cave* (now known as *fountain cave*) near the railroad bridge of the Chicago, Milwaukee and St. Paul railway. This locality was specially examined. The layers of the limerock are, it is true, disturbed along the immediate river bluff, and are mixed in some confusion with coarse drift, but at points further from the river the beds continue along horizontal and unbroken, so that the formation itself cannot be said to be disturbed. Dr. Owen attributes rightly this broken condition, so far as the blocks seem to lie on drift materials, to the action of water, probably that of the river at some higher stage. The beds were undermined and dislodged, but the blocks were not far transported.

The St. Peter sandstone. This sandstone is seen in the bluffs of the Mississippi from the Hennepin county line to the Washington county line; and by reason of the breaking down of the overlying Trenton, wherever former streams have run, and the easy erosion of this rock, it also becomes the surface rock in a number of tributary valleys. In the city of the St. Paul there is a large expansion of the area of the St. Peter sandstone over the low level through which Phalen's creek enters the Mississippi. This extends more than a mile north of the river, and probably has a ramifying prolongation northward toward McCarron lake making a connection with the area of the St. Peter where the natural dip would bring it to the surface in the central parts of the county. Most of the lakes, and the deep valleys that exist in the rolling portion of the county, directly north from St. Paul, are based on the St. Peter sandstone, but they are bottomed by drift clays. These old valleys, now buried by drift materials, and other re-entrant areas cut in the margin of the Trenton limestone in the eastern part of McLean, where the St. Peter sandstone can be seen under the gravel deposits of the high terrace, without the presence of the Trenton limestone, were caused by the surface erosions which removed the limestone in pre-glacial (or inter-glacial) times; for there is every evidence to show that the limestone once was continuous across the Mississippi valley from Washington county to Dakota county as well as from Ramsey to Hennepin, although below the mouth of the Minnesota the gorge of the Mississippi is much wi ler and the old bluffs are obscured by the drift of the last glacial epoch.

The St. Peter sandstone is about 150 feet thick. It has no noteworthy variations of character, so far as seen in Ramsey county, and it has already been described so many times that its lithological features need not be repeated. At the base of Dayton's bluff, in the eastern part of the city of St. Paul, were seen, some years ago, the same pores, or *Arenicolites* tubes, that have been mentioned in the reports on Dakota and Rice counties.*

Formations below the St. Peter sandstone in Ramsey county. Several deep wells have penetrated the strata that lie below the St. Peter sandstone. A well drilled in 1877 at the reform school, S. E. ¼ of sec. 34, Rose, had the

* Compare vol. i., p. 656.

following record according to Mr. F. McCormick, secretary of the school. This well, however, does not pass through the St. Peter sandstone.

The deep well at the reform school.

1.	Black soil, loamy,	2 feet.
2.	Gravel,	3 feet.
3.	Clay,	½ foot.
4.	Coarse gravel,	13 feet.
5.	Fine sand,	1 foot.
6.	Coarse gravel,	1 foot.
7.	Fine sand,	1 foot.
8.	Coarse sand,	13 feet.
9.	Boulders,	2 feet.
10.	Limerock,	½ foot.
11.	Clay,	3 feet.
12.	Sand, with water,	2 feet.
13.	Shell rock, with clay	6½ feet.
14.	Hard limerock,	7 feet.
15.	Clay,	2 feet.
16.	Hard rock,	1 foot.
17.	Blue clay,	4 feet.
18.	Hard rock,	4 feet.
19.	Blue clay,	1 foot.
20.	Limerock,	3 feet.
21.	Clay; light colored,	6 feet.
22.	Clay; dark colored,	5 feet.
23.	Clay; yellow,	4 feet.
24.	Clay; blue,	5 feet.
25.	Clay; blue, very hard,	8 feet.
26.	Blue clay,	28 feet.
27.	Limestone; hard,	1 foot.
28.	Blue soapstone,	6 feet.
29.	Limerock,	3 feet.
30.	Blue soapstone,	3½ feet.
31.	Limerock,	1½ feet.
32.	Blue limestone,	28½ feet.
33.	Blue clay,	5 feet.
34.	White sandrock,	77½ feet.
	Whole depth,	252 feet.

An abundant supply of water was obtained at the depth of 150 feet. This supply, however, was not tested until after the well had been bored one hundred feet below it. The drill at that point became fixed and immovable, so that the contractor was wholly unable to proceed further, when, after experimenting with pumps, it was found that the supply was sufficient for all practical purposes. The water was obtained after drilling about ten feet in the limerock of No. 32. From this source the water rose in the well about 80 feet. The water is supposed to be of excellent quality. [F. McCormick.]

The drift was found thirty-six and a half feet in thickness; the entire Trenton 114 feet, so far as preserved above the St. Peter sandstone. This cannot be assumed, with entire certainty, to have been the original thickness of the Trenton formation, but it may have been several times as thick when first it became dry-land. The rest of the palæozoic, the whole of the mesozoic and of cenozoic time, including the operation of the drift agents, has elapsed; and, if the erosions that are seen to have taken place in other rocks may be taken as a guide, the Trenton formation may be considered to have covered the whole of Ramsey county, and to have been as thick as it is now found to be in Goodhue and Rice counties.

The deep well at elevator "B," St. Paul.

This is situated near the centre of the southwest quarter of the southeast quarter of section twenty-five, on the line of the St. Paul, Minneapolis and Manitoba railroad, and begins about 855 feet above the sea. The entire depth is 850 feet. Water stood at thirty-five feet below the surface during the entire progress of the work.*

1.	Dark gray, fine sand,	40 feet.
2.	Dark gray, fine sand,	40–58 feet.
3.	Light gray, shaly limestone,	58–63 feet.
4.	The same,	63–69 feet.
5.	Light yellowish gray, very fine grained, arenaceous (?) shaly,	69–83 feet.
6.	Fine-grained, white sandstone,	83–235 feet.
7.	Light gray; somewhat argillaceous, fine-grained, apparently sandstone,	235–265 feet.
8.	Buff magnesian limestone in angular fragments,	265–300 feet.
9.	Fine-grained, white quartz sandstone, water-rounded,	300–320 feet.
10.	Buff magnesian limestone,	320–335 feet.
11.	Fine, light yellowish powder, no grains visible,	335–375 feet.
12.	White sandstone, in small part iron-rusted, water-rounded,	375–436 feet.
13.	Light buff, gritty stone, like the core of the diamond drill in the Harvester Works well,	436–437½ feet.
14.	Sand, light gray, or nearly white,	437½–478 feet.
15.	Light gray shale,	478–515 feet.
16.	Very fine bluish shale,	515–523 feet.
17.	Very fine light gray shale,	523–529 feet.
18.	Very fine light yellowish gray sandstone, somewhat argillaceous,	529–540 feet.
19.	Very fine sandstone, with some dark green grains,	540–560 feet.
20.	Very fine shale, olive green,	560–589 feet.
21.	Nearly the same as the last, with some sand,	589–604 feet.
22.	Light gray shale, with some sand,	604–672 feet.
23.	Fine-grained sandstone, dark gray,	672–738 feet.
24.	Light gray shale, very fine-grained,	738–761 feet.
25.	Very fine, dark buff, siliceous, non-effervescing, with occasional rounded quartz grains, but generally homogeneous,	671–774 feet.
26.	Green shale, or ground up greenstone,	774–798 feet.
27.	Same as No. 25, but gray rather than buff,	798–820 feet.
28.	Same as the last; fine buff sandstone,	820–828 feet.
29.	Unknown,	828–850 feet.

* The drillings from this well were examined by Mr. Warren Upham, through the courtesy of Mr. W. S. Timerman.

The first well drilled at the St. Paul Harvester Works.

This was located in the rattling, or chipping, room of the foundry, at a hight of about fifteen feet above Phalen creek near by, or about 863 feet above the sea.* This well was drilled by W. N. Cary, to the depth of 582 feet (claimed by Mr. Cary to be 602 feet), when his work ceased. In the winter of 1882–3 it was continued, by a diamond drill, under the management of Joseph Susor, to the depth of 626½ feet. The only samples preserved from this well, so far as known, were from the part drilled by Mr. Susor. They are from 10, 20, 30, and 44 feet below 582 feet. These are pulverized, darkish gray, shaly, siliceous, probably dolomitic, agreeing with the core obtained from the second well at a corresponding depth. Owing to the supposed bed of iron and iron ore (reported to be very hard to drill) in the first well, *a second one was drilled*, at a point about fifteen rods north from the first, on land about eight feet higher, or approximately 871 feet above the sea. Mr. Cary drilled in this well, during the summer and autumn of 1882, to the depth of 515½ feet. Mr. Susor, with a diamond drill, penetrated 156 feet further, or to a total depth of 671½ feet. A very complete set of the samples from this well were courteously supplied by Mr. Kirk, from the drillings preserved in the office of the Harvester Works at St. Paul. Mr. Cary drilled a hole six inches in diameter; the core obtained by the diamond drill is about an inch in diameter. The water stands constantly in each well at 35 or 40 feet below the surface. The following descriptions of these drillings are essentially as prepared by Mr. Upham. Rock was reached at 235 feet.

1.	Dark, sandy and clayey loam,	1–10 feet.
2.	Gray sand and fine gravel containing pebbles up to three-quarters of an inch in diameter,	10–20 feet.
3.	Same, with pebbles up to one and a half inches in diameter,	20–30 feet.
4.	Yellowish coarse sand,	30–40 feet.
5.	Yellowish sand and gravel, with pebbles up to one-half inch,	40–50 feet.
6.	Yellowish sand and fine gravel,	50–60 feet.
7.	Light gray sand and fine gravel,	60–70 feet.
8.	Light gray sand and fine gravel,	70–80 feet.
9.	Light gray sand and fine gravel,	80–90 feet.
10.	Light gray, fine sand and pebbles up to one and one-half inches, slate, greenstone, etc.,	90–100 feet.
11.	Light gray, fine sand and pebbles up to three-quarters of an inch, including some of granite,	100–110 feet.
12.	Light gray sand and gravel, with small pebbles of granite, greenstone, etc.,	110–120 feet.

* The railroad at the Union depot, St Paul, is 701.5; water in Phalen creek, at the highest crossing of the St. Paul, Stillwater and Taylors Falls railroad, 845; water in this creek at the Harvester Works, 848; Phalen lake, 854. Concerning the alleged discovery of a deposit of metallic iron and magnetic iron ore in this well, beginning at the depth of 560 feet, and reaching below at least 42 feet, see the *Pioneer Press* for Aug. 24, 1882.

13. Light gray sand and gravel, with small pebbles up to one-half inch, 120–130 feet.
14. Light gray sand and fine gravel, - - - 130–140 feet.
15. Light reddish gray sand, with rare greenstone pebbles up to one and one-half inches in diameter, 140–150 feet.
16. Light reddish gray sand, with pebbles (rare) up to two inches in diameter, 150–160 feet.
17. Light reddish gray sand, with pebbles up to one and one-half inches, 160–170 feet.
18. Light gray sand, with pebbles up to one inch in diameter, 170–180 feet.
19. Coarse gravel, largely made up of pebbles (from the northeast) up to one and one-half inches, 180–190 feet.
20. Similar to last but containing more sand intermixed, 190–200 feet.
21. Same, mostly finer, but with occasional pebbles up to two inches (one a reddish porphyry, from lake Superior), 200–210 feet.
22. Coarse gravel, mostly pebbles up to two inches, with little sand, 210–220 feet.
23. Yellowish sand, with few gravel stones (these probably from the stratum above), 220–230 feet.
24. The pulverized drilling contains a large proportion of broken, angular fragments (up to one-third of an inch) of buff magnesian limestone (with some sand and gravel stones); the rock is said to have been struck at two hundred and thirty-five feet, 230–240 feet.
25. Light yellowish, very fine powder, slightly caked in the box, including no coarse particles or fragments; effervescing freely, 240–250 feet.
26. Light buff; drillings intermediate in character between the last two, 250–260 feet.
27. Similar to the last, but more arenaceous, mainly very fine, granular (fractured), angular (also containing sand and occasional small pebbles, doubtless from above two hundred and thirty-five feet,) 260–270 feet.
28. Light buff magnesian limestone, in fine (from dust up to one-twelfth of an inch) angular fragments, with grains of rounded quartz, 270–280 feet.
29. Magnesian limestone, yellowish buff, containing a considerable proportion of white quartz particles, some of them rounded by water, up to one-twentieth of an inch in diameter, with arenaceous chert and quartz geodes, 280–290 feet.
30. Mostly very fine yellowish powder (dust) nearly like No. 25, but also containing frequent angular particles up to one-quarter of an inch in diameter, of magnesian limestone, 290–300 feet.

[The samples from three hundred to three hundred and fifty were wanting and could not be found nor learned of. This part is probably limestone, which lies both above and below.]

36. Mostly fine, light gray powder, with angular fragments up to one-eighth of an inch, of fine-grained magnesian limestone that effervesce freely, 350–360 feet.
37. Sandstone; light yellowish, fine, largely (half or more) composed of white quartz grains, well rounded, up to one-thirtieth of an inch in diameter, with dolomitic powder, - 360–370 feet.
38. Limestone; light yellowish buff, nearly like No. 36, excepting color, - 370–380 feet.
39. Sandstone; light gray; all the grains water-rounded mostly one-sixtieth to one-twentieth of an inch in diameter, or finer; none coarser than one-twentieth of an inch, - 380–390 feet.
40. Same as last, mostly beautifully rounded white quartz grains, with pieces of coal, metallic iron and furnace slag, 390–400 feet.
41. Same as last, becoming more yellowish, with a few bits of coal and battered scales of metallic iron. - - 400–410 feet.
42. Same, with a few grains of shining black coal and scales of metallic iron, the latter largely oxydized, 410–420 feet.
43. Same, but finer and whiter; grains not exceeding one-fortieth of an inch, all well rounded, with some pyrite, and a few iron scales, 420–430 feet.
44. Same as last; very light yellowish, with slight traces of coal and iron scales, 430–440 feet.
45. Same as the two preceding, with a few grains of pyrite with grains of rounded quartz firmly cemented to them and scales of iron, 440–450 feet.
46. Still finer water-worn sandstone, very light gray, almost white, - - 450–460 feet.

47. Coarse (up to one-twentieth of an inch), with much also that is very fine; yellowish gray; well water-worn, with iron scales (rusted) and grains of a black scoria; also contains traces of green shale and some dolomitic powder, - 460–470 feet.

48. Very fine; very light yellowish; well rounded; much like No. 46, with coal (anthracite), one piece being three-tenths of an inch in diameter; scoria and scales of iron, 470–480 feet.

49. Very fine; light leaden gray, arenaceous (and perhaps dolomitic) shale; (caking somewhat in the box) effervesces, 480–490 feet.

50. Very fine (more so than last); light dusky gray, arenaceous shale; caking harder than the last, 490–500 feet.

51. Similar to the last but more arenaceous, with much sand of white quartz, up to one-hundredth of an inch in diameter, - 500–515 feet.

[At five hundred and fifteen feet the pulverized drillings stop, and the remainder of this well is represented by samples of the core of the diamond drill, about one inch in diameter.]

The diamond drill cores obtained in the second well below the depth of 515½ feet had the following characters, as described by Mr. Upham, viz.: at 555 feet a piece six inches in length was gray, compact and hard, fine-grained sandrock, probably dolomitic, inclosing occasional shaly, darker laminæ, and having in some portions dark specks of greensand; at 578 feet a core eighteen inches in length showed the same rock; at 590 feet a core twelve inches in length was of a light, yellowish-buff, compact and hard, very fine-grained sandrock, probably dolomitic, containing mica-scales (?) (very minute shining facettes), not shaly, and having less greensand; at 626 feet a piece of the core, eleven inches in length, was similar to the last, but with light-green streaks and irregular blotches, up to one-quarter of an inch thick, vertically, yet not more than three-quarters of an inch long, thinning at each side to one-twentieth of an inch or less in thickness, with some fine shale; at, and below, the depth of 650 feet, a core measuring about five feet in length was preserved, representing a thickness of rock strata about ten feet thick, consisting of a rock that was hard and compact, alternately arenaceous and shaly, probably dolomitic, in color about one-tenth part buff, about one-half dusky gray, and about two-fifths dark green; the layers of dark greensand, not so hard as the other portions, vary from one-twentieth of an inch to two or three inches in thickness, being interbedded with the dusky and buff layers.

In this well the rock was struck at the depth of two hundred and thirty-five feet. This was the same as seen in the river at Red Rock, and at points further down the Mississippi, amounting in its full thickness to 150 feet. Then came 100 feet of sandstone, the stratum which appears at the river level a few miles north of Hastings; the "pieces of coal, metallic iron and furnace slag" which Mr. Cary *discovered* in this part of the well, were probably derived from the furnace and fuel rooms of the Harvester Works, and through some inadvertence of the workmen was introduced from above. This sandstone, which is the stratum which appears at Jordan, a short distance above Shakopee, in the Minnesota valley, and hence called *Jordan sandstone*, seems to have gradually become shaly through a thickness of thirty-five feet, acquiring greensand, and passes into a dolomitic shale, and even into a dolomite, in which last condition it is the St. Lawrence limestone, and it appears at St. Lawrence, in the Minnesota valley, and in the lower part of the bluffs at Red Wing. In this shaly and greensand member the well penetrated about 180 feet.

In West St. Paul are numerous artesian deep wells. These are situated on the low land within the ancient rock gorge and vary in depth from 200 feet to 375 feet. The flow of water is sufficient to rise from 20 to 30 feet above the natural surface. The water obtained is very clear, pure and wholesome. It is soft. The source is the St. Croix sandrock. It appears, from the testimony of owners, that a flow of artesian water generally begins at the depth of about 100 feet, and increases as the depth of the drill increases. These flowing wells are owned by Isaiah St. Pierre, Wm. A Fitzer, C. B. Lawton, Matt. Eaton, the city of St. Paul, the Crescent Creamery company, the Spa Bottling company, M. Bruggamann, Horman and A. M. Lawton, and by the Minnesota and Northwestern Railway company.

The well of M. Bruggamann is 371 feet deep, situated at the brewery, near the foot of the St. Peter-Trenton bluff. It flows constantly, and rises now about 20 feet above the surface, although it formerly rose about 30 feet. It is said to be obstructed by sand that is accumulated in the bottom of the well.

The well of Horman and A. M. Lawton is 244½ feet deep. It passed through about 90 feet of clay, sand, etc., belonging to the alluvium of the valley, from 50 to 60 feet of hard rock, probably limestone, from below which, water rose to the surface. The drill then passed through some softer rock (probably the

Richmond sandstone) about 30 feet, and then about 70 feet of harder rock, the probable eqnivalent of the Lower Magnesian limestone, striking sand, from which a strong flow of water rose to the surface.

The well of the Crescent Creamery is 235 feet deep.

Mr. Isaiah St. Pierre's well is 225 feet in depth. Water here began to overflow at about 100 feet, and increased to 225 as the drilling proceeded, but the greatest increase occurred at the point where the well stopped. Water rises 30 feet above the natural surface. Before striking the bed rock this well passed through about 75 feet of fine clay, an alluvial deposit of the river, and the equivalent of that which is used at points a little further east, for brick-making.

Several wells have been sunk to greater depths on the high land further south, which is underlain by the Trenton limestone, with the expectation that the artesian flow would also be obtained there. But although some have gone down over 1100 feet, water rises only a little higher than in the wells drilled on the bottom-land.

This supply of water is used by the city of St. Paul for fire protection on the west side of the river, and the supply is found to be ample. It is well known that the porous St. Croix sandstone is an extensive stratum underlying this part of the state, and that it uniformly supplies pure water which sometimes flows over at the surface. The amount of water that might be taken from this sandstone is practically inexhaustible; probably no number of wells that could be sunk into it would be able to appreciably diminish the volume of flow in the others. It is worthy of consideration whether the entire city of St. Paul could not cheaply procure pure water for domestic purposes by sinking several large wells to this sandrock and by the construction of pumping-stations and reservoirs, distribute it through the city much cheaper than that which now comes from the lakes in the northern part of the county.

The deep well at Mendota.

The flowing well at the railroad station at Mendota is 857 feet deep. It begins at 63 feet above the Mississippi at low water, within the river gorge, and so near the rock bluff composed of the Trenton limestone and St. Peter sandstone that the drill encountered some of the old, fallen masses of the limestone at some depth below the top of the sandstone. This sandstone is visible in the immediate bluff, about fifty feet distant, and rises 47 feet above the top of the well, which latter is about 750 feet above the level of the sea.

1.	Limestone. [Fallen masses of the Trenton.—N. H. W.]	22 feet.
2.	Brown sandrock,	60 feet.
3.	Blne shale,	30 feet.
	[The last of the above strata, designated blue shale, is probably not all blue shale. It holds the place of the Shakopee limestone, and is about on the horizon where the known upper strata of that formation, about a mile east of Hamilton, with the theoretical dip which must be assumed toward the northeast, would require the Shakopee.]	
4.	Sandrock,	35 feet.
5.	Magnesian limestone,	145 feet.
6.	Sandrock,	95 feet.
7.	Gray shale,	50 feet.
8.	Green shale,	110 feet.
9.	Limestone,	10 feet.
10.	Blue shale,	30 feet.
11.	Sandrock,	50 feet.
12.	Gray shale,	40 feet.
13.	Green shale,	35 feet.
14.	Very hard red sandrock, inclosing beds of red shale,	145 feet.
	Total depth,	857 feet.

Of these, No. 2 is the lower part of the St. Peter sandstone, No. 3 seems to represent the Shakopee limestone, No. 4 the Richmond sandstone, No. 5 the main body of the Lower Magnesian limestone, No. 6 the Jordan sandstone, Nos. 7, 8, 9 and 10 the Mendota shales and limestone, of which No. 9 is the St. Lawrence limestone, No. 11 the Dresbach sandstone, Nos. 12 and 13 the lowest shale seen at Dresbach, the Dresbach shale, and No. 14 the Potsdam sandstone, the equivalent of Nos. 17–25 of the Hastings deep well, and No. 7 of the Red Wing well.

Mr. W. E. Swan, who drilled this well, remarks that "No. 5 of this well seems to be the same limestone that outcrops at Hastings. We struck a crevice when we got 40 feet into this stratum from which the water began to flow at the rate of 40 gallons per minute. A second flow of water was obtained from No. 11 (sandrock). When we got through this sandrock the well flowed 300 gallons per minute. After we got through drilling we tubed the well and separated the upper vein of water from the lower vein, and we found the lower water to be much softer than that which comes from the upper vein. We also found that the water from the lower vein rose 14 feet above the surface, while that from the upper vein would rise only four feet. No water was obtained from the red sandrock (No. 14); there was no increase in the flow after passing through No. 11."

The well at elevator B exhibits some irregularity. The "blue shale" which at Mendota seems to represent the Shakopee, below a thickness of a hundred and twenty-nine feet of sandstone (including forty-seven feet visible in the face of the bluff), is not mentioned at all. It may have been passed without being noted in the one hundred and fifty-two feet reported as sandrock, or it may be represented by Nos. 7 and 8. In the latter case it would coincide with the recognized dip of the Trenton between Mendota and elevator B, which amounts to about twenty-five feet, bringing the top of the Shakopee at Mendota at about six hundred and fifty-five feet above the sea level, and at elevator B six hundred and twenty feet. The underlying white sand (twenty feet) would be the Richmond sandstone which in the Mendota well is reported to be thirty-five feet. This parallelism, however, requires the reduction of the main body of the Lower Magnesian from one hundred and forty-five feet, reported in the Mendota well, to fifty-five feet as reported in the elevator B well. The same stratum at Lakewood cemetery in the western part of Minneapolis city is given at eighty-five feet.

In the case of the wells foregoing it seems necessary to state that the Shakopee formation dwindles toward the north and northeast in this latitude, as already well known further south. The sandy and clayey constituents increase at the expense of the calcareous. This is true also of the main body of the Lower Magnesian which at Hastings, and apparently at Stillwater, embraces one or more strata of white sand from ten to twenty feet in thickness. These are comparable to those thinner beds of white sand that are intercalated in the Shakopee, seen at Northfield.

Any person who has had occasion to record and compare the reports of well drillers, or to obtain the drillings of wells for his own examination, will appreciate the difficulties and the uncertainties of such records. The drillings are not carefully preserved; the depths from which they are obtained are not accurately stated, nor even known, and the changes in the rock from stratum to stratum cannot be located with precision. Some broad stratigraphic distinctions, however, can generally be made out.

THE DRIFT.

Till. This portion of the drift deposits is nearly always red, or copper-colored, in Ramsey county, but it is locally affected by the shales of the Trenton, as seen along some of the cuts by the railroads between St. Paul and Minneapolis, so that it is blotched by green or blue. As a till it is apt to become rather gravelly, and even to be converted into gravel and sand wherever, in the courses of glacial drainage, the materials were washed and the clayey ingredient was removed by the transporting action of the turbulent waters. It is also covered, very generally, by later, and finer, deposits, such as loam, sandy loam, pebbly clay, and by the terrace-deposits of the rivers. Further, a gray till is seen in some places, occupying considerable areas, and its relation to the red, and to the gray pebbly clay which in some places overlies the red till, seems to be the same as that of some isolated gray till areas in Dakota county.*

* See p. 85.

At St. Paul the red hardpan is found uniformly in excavating for buildings in all that low area about the level,* and in the deep cuts through the gravelly bluff north of East Third street. Although here it is covered with sometimes more than forty feet of lighter-colored drift-materials, mainly gravel and sand, it emerges from under these immediately on getting outside the valley either north or south. Its relation to these stratified materials is partly that of underlying them and partly that of gradual transition into them horizontally and also perpendicularly. At those points where some deep excavation has been carried on, as along Mississippi street, and at the cuts made by the St. Paul and Northern Pacific railroad, these relations are well exhibited. The gradual transitions from the till to gravel and sand, as well as the occasional occurrence of small masses of till in the midst of assorted and stratified gravel and sand, show that the two were being accumulated contemporaneously, or remittently. The agent that brought the till also brought, at the same time, the gravel and sand, the only difference that can be deduced from the facts being referable to the difference in the local circumstances attending, and therefore modifying the method of immediate deposition. Where water was present in sufficient quantity to wash it and assort it and stratify it, then the whole was converted to gravel and sand. Otherwise it was deposited as till. It is for that reason that along the great valleys are strewn vast deposits of gravel in the form of terraces, and that such gravel forms extensive plains where formerly waters were spread that bore detrital matter directly from the ice-fields of the contiguous region. Such waters and such ice, bearing such materials, were concentrated at St. Paul, by the action of the Trenton plateaus which have been described, one running northwest and one northeast from St. Paul. This powerful erosive agent entered the great valley where Phalen's creek now enters it, and it operated not only to open and enlarge the break in the Trenton limestone, but to cover it, and the surrounding bluffs, with the changed till which was supplied by the ice and water. Hence as one passes northward, at this place, from the Mississippi, the cuts reveal a constantly increasing percentage of unassorted drift, and it finally is changed entirely to unwashed till.

The following figures were sketched from nature, intended to show some of the appearances in the drift just at the point where the waters were not

* In some of the excavations at St. Paul, in the lower portion of the city, but not near the river a gray till is found and there may be considerable of it even under the water of the river itself, filling a deep gorge.

able to wash completely and arrange in concordant strata, all the crude till that was supplied by the moving ice.

1
2

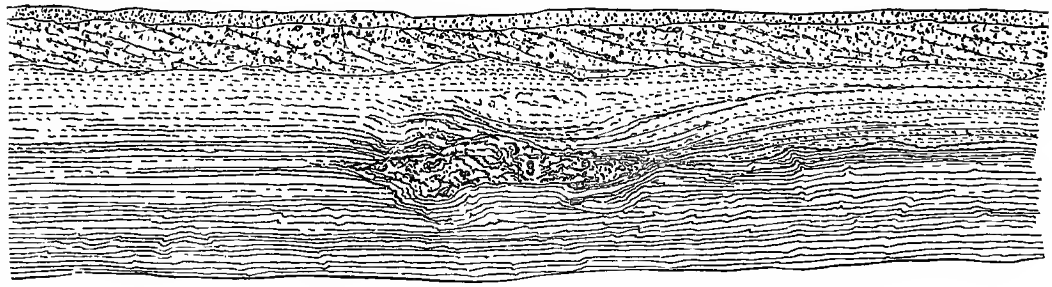


FIG. 24. SECTION OF THE DRIFT ON MISSISSIPPI STREET.

EXPLANATION OF THE SECTION ON MISSISSIPPI STREET.

1. Sandy loam, underlain by gravel and sand; loam, 2–5 feet thick; gravel and sand, 10 feet.
2. Fine sand, handsomely stratified, passing below to fine clay, seen 15–18 feet.
3. Lens of red till, embraced in the strata of fine clay, about 4 feet thick.

The point of interest in this section is the lens of till in the midst of strata of fine clay, both being red. In other places adjacent the strata pass into till, retaining some of their characters of stratification; lines of gravel, or of stony till, are evident in the fine clay strata, some of them being only six or eight inches thick. The stratification is seen in some cases, running into, and permeating the till so that it is difficult to say whether it should be styled till or stratified clay. Yet, in such a case, it is not entirely clay, since it embraces stones (10 inches and less) and pebbles that are water-worn. Some stones also are glaciated. The till changes horizontally, by the abstraction of the clay, to pebbles and gravel, but it frequently shows a few alternations of till with gravel or with gravel and sand.

1
2

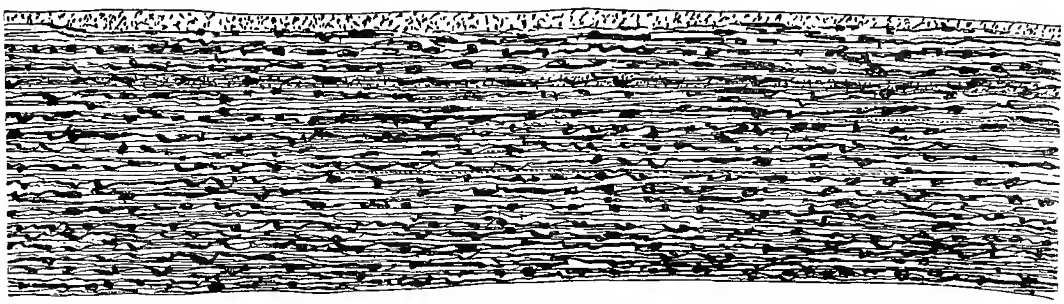


FIG. 25. DRIFT SECTION NEAR HAMLINE.

EXPLANATION OF FIG. 25.

1. Loam, 2–4 feet.
2. Stratified materials, but not completely water-assorted; lumps of till, with pebbles and stones, are mingled with the stratified arrangement.

This figure illustrates the manner of deposition when there was a steady supply of moist till too great for the water there acting to completely work over and wash. The whole is arranged in nearly horizontal stratification, but scattered through the strata of finer materials, and constituting a large portion of the whole section, are lumps of till that did not lose their clay but rolled along with the pebbles and finally were buried under other loose materials of the same kind. Some strata consist entirely of fine materials for short distances, but they were compelled to accommodate themselves to the presence of coarser, and to include them in their final posé.

Dayton's bluff, and eastward, and southeastward, is entirely a morainic area, with small lakelets in deep depressions, and very tortuous contours. The depressions in some cases are due to excavations in the St. Peter sandrock, through the removal of the Trenton limerock, amounting to over a hundred feet. The region of the highlands on which runs the eastern border of the county, east of New Canada, is essentially one of the red till; but over the immediate surface the soil is fine and rather clayey or loamy. On the opposite side of the county, on the plateau that diverges from St. Anthony hill, in the western part of Rose township, the red till is covered by a pebbly gray clay, which in some places could properly be styled gray till. It furnishes a clayey soil and sometimes contains bits of Cretaceous shale. The gray, in general, lies on the red, but sometimes there is a mingling of red and gray. In other places they both seem to merge into a pebbly loam which itself becomes the prevalent stoneless surface loam and black soil. In this mingling there can be seen, toward the bottom of the bluffs where cut by highways, one or two alternations of red and gray strata. A stratum of gray till is seen under the red on the "short line" of the Chicago, Milwaukee and St. Paul railway, about three miles from the Union depot, but this may be due to the local effect of the presence of the shales of the Trenton. Several alternations of red and gray till, and patches of one within the other are visible at St. Anthony Park; and in the gray is much debris of the Trenton shales, with characteristic bryozoa and brachiopods, with crystals of selenite.

In Mound View is a conspicuous and important area of gray till. A continuous moraine of rolling gray till extends north and south nearly across the centre of the township. It includes the well-known *mounds* of the township. The top of the highest knobs, in sec. 10, are about 225 feet above the surrounding low-land level. This till has an overlying stratum of pebbly clay which on the hill, N. W. ¼ sec. 22, is eight feet thick. The boulders are mostly of gray granite and gneiss, with no gabbro nor cupriferous rocks. Near Sunfish lake, on sec. 15, was seen one piece of the well-known northern limestone. Toward the southwest this gray till apparently passes below the sandy soils of the Rice creek valley, and reappears on the highlands in the northwest part of Rose. This reaches to N. E. Minneapolis wherever it is not covered by later sand or sandy loam. It is rather pebbly than stony where it constitutes the surface. It is perhaps the equivalent, in age, of the Minneapolis brick-clay, and of the gray clay seen below stratified sand at St. Paul. It is again seen on the University campus where it is exposed by recent excavations for the foundations for the students' Christian Association hall, near Tuttle's creek, and on Pleasant street. At the latter points, which are within the valley of the Mississippi at East Minneapolis, it lies underneath a sand which is apparently a glacial deposit at the high-water stage of the Mississippi. This sand is covered by a course of pebbles and sand with a few stones, a mixed and apparently disturbed debris from the downthrow of some other beds. The pebbly gray till is essentially the same that extends under the flat tracts in the northern part of the county, but it is covered by a sandy loam or clayey loam which is in some places distinctly laminated horizontally.

Modified drift. Throughout the country the red till is apt to be mingled with assorted materials. But along the Mississippi, these materials cover superficially, and replace to a depth of a hundred feet or more, the unmodified glacier deposits forming, in some instances, marked terraces of gravel and sand. Such terraces are most conspicuous below St. Paul, on both sides of the river, but they continue, with more or less modified outlines, all the way to the west line of the county. They spread widely over the central portions of the city of St. Paul, but they have been removed extensively for grading purposes. While this grading was going on some perpendicular sections were exposed, and some sketches were made, showing the nature of stratification and the relation of the later deposits to the earlier.

Section on Sibley street, St. Paul.

1.	Loam,	2 feet.
2.	Stones and gravel, mostly limestone, also boulders, large stones sloping to the S. E. and E. toward Phalen's creek valley,	12 feet.
3.	Sand and gravel in beds irregularly alternating with No. 2. Some beds of gravel are two feet thick, - -	10 feet.
4.	Stones and gravel. In this are some northern boulders and limestone pieces, also pieces of green shale; the large stones sloping E. and S. E., - - -	20 feet.

5. Red sand, horizontally and somewhat obliqnely stratified; often fine and clayey, 8 feet.
6. Red till. Seen. - - 12 feet.

NOTE. No. 6 above is often of the color of common red brick, and is very hard and compact. The npper portion in some instances shows a kind of lamination which still holds stones, and is very sandy showing the same structure and composition as seen in the cut near Hamline, figure 25. In other places it passes into No. 5 gradually. But there is a very sudden and marked transition from No. 4 to No. 5, indicating a distinct deposit and a different origin. The iron in No. 4, and in all above, is hydrated, giving the whole a yellowish gray or olive cast of color. Although No. 5 consists of sand, and will admit water as freely as No. 4, it has only the red, non-hydrated, peroxide of iron. Nos. 2, 3 and 4 make substantially one great deposit, and are derived from the wash of the gray till in the act of deposition. The boulders and stones in No. 6 are prevailingly of crystalline rock, there being but rarely a piece of limestone; those in No. 4 are, nine-tenths of them, from the limestone of the Trenton.

Descending from Sibley street toward Wacouta street, and so toward the general centre of the tributary valley in which these excavations were made, Nos. 2, 3 and 4 gradually taper out, becoming no thicker than three feet, and other deposits replace them unconformably.

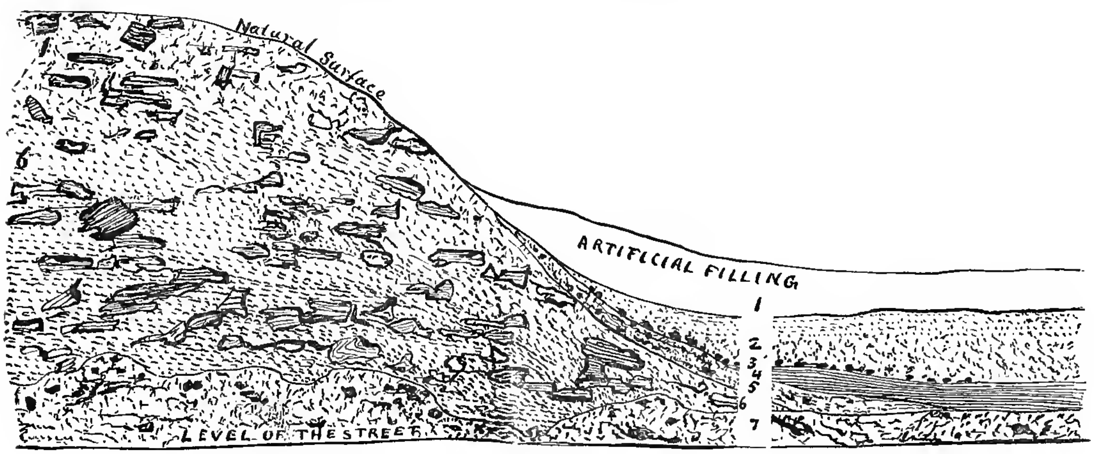


FIG. 26. SECTION OF THE VALLEY DRIFT ON FIFTH STREET, NEAR SIBLEY STREET, ST. PAUL.

EXPLANATION OF FIG. 26.

1. Artificial filling, 6–8 feet.
2. Quicksand, 0–8 feet.
3. Stones and pebbles, 1 foot.
4. Laminated brick-clay, gray, - 0–4 feet.
5. Clayey and stony, somewhat till-like, 0–3 feet.
6. Gray stones and gravel, mainly a residuum from the gray till from the northwest. The boulders are prevailingly blocks of Trenton limestone. Seen, 0–50 feet.

NOTE. In some places No. 6 seems to have had a thickness of nearly 100 feet. These cuts were exposed in 1877 when the grading was begun which has resulted in the removal bodily of the drift-materials of several blocks for a depth of 20–75 feet, for the double purpose of leveling and lowering the original bluffs, and of filling the low land near the river now crossed by Third street and extending sonth from Third street to the river, over which now run the railroads in their approach to the Union depot.

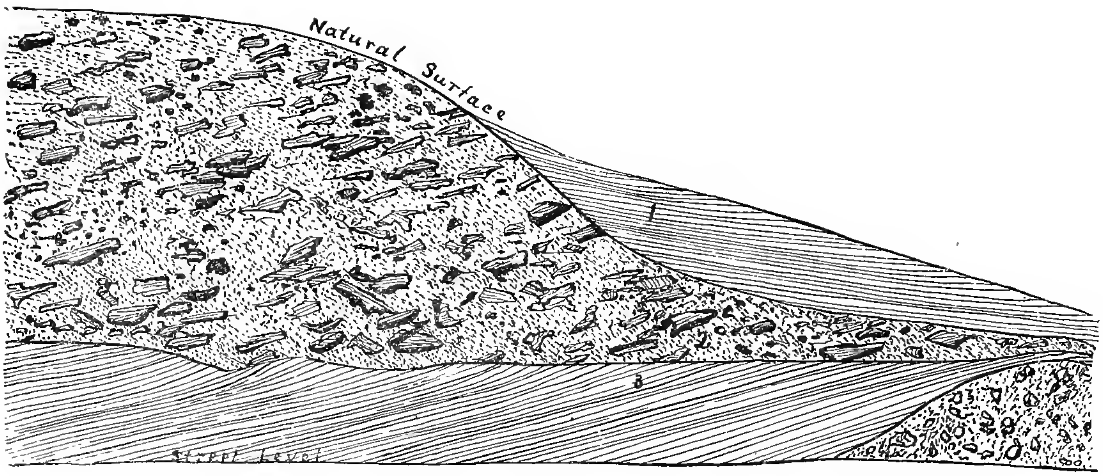


FIG. 27. SECTION ON FIFTH STREET, BETWEEN SIBLEY AND WACOUTA STREETS, ST. PAUL.

EXPLANATION.

1. Brick-clay, gray; the same as No. 4, in figure 26, 0–8 feet.
2. Stones, boulders and gravel, same as No. 6, in figure 26. The fine gravel shows a prevailing water-formed structure sloping N. W., the probable direction in which the glacial waters flowed; while the flat surfaces of the limestone blocks present their longer sides with a prevailing slope S. E., thus affording the least obstruction to the current. Stones can be seen thus arranged in the beds of torrential streams. 2–30 feet.
3. Red, laminated clay, very siliceous ("tripoli"). Seen, 3–10 feet.
4. Stony, compact, hard red till. Seen, 8 feet.

No. 1 becomes, at the crossing of Wacouta street, about 16 feet thick, and continues horizontally bedded, but with a gentle, general slope toward the N. E. or toward the centre of the valley. Its lower portion also changes to quicksand. The gravel and sand of No. 2, of the last section, lie sometimes on No. 4 without the intervention of No. 3. The limestone masses, as well as the granite boulders in No. 2 have their angles rounded and decomposed, some masses even falling to pieces in the process of digging, though this is of course due largely to the quality of the rock. They are all water-worn and stained, rather than glaciated. The limestone masses are generally changed in color through and through, as if having been water-soaked in contact with air, or alternately in contact with air and water, for a great many years. They are not blue and fresh as water-soaked specimens are from a quarry, nor so well preserved as masses seen along the gorge below the falls of St. Anthony. There are spots below Wacouta street where this number (No. 2) becomes clayey, making a gray stony hardpan, resembling that which covers the western part of Hennepin county, but still very gravelly and stony. This character does not rise above the lowermost two feet, so far as seen in the excavations on Wacouta and Sibley streets. Below Wacouta street brick-clay is seen lying *below* a layer of stones and gravel, and this position can be traced in the opposite bank to some distance above Wacouta street, the clay gradually becoming thinner till it allows the overlying gravel and stones to come into contact with those of No. 2, the only remaining difference between the upper and lower parts being the difference in *throw*, or slope, of the larger stones. It is supposed to be the equivalent of the brick-clay at Minneapolis, at lake Minnetonka and at Carver, though it does not everywhere make brick of the same color. It lies directly on the gravel and stones of No. 2 with a sudden transition, indicating some great and sudden change in the force depositing the material, followed again by a revival of the former drainage force, giving origin to the overlying stones and gravel. It is wholly embraced within the period of deposit of the gray or later drift.

That which is of special interest here is the red laminated clay, No. 3. This is the result of the action of the water on the red till. It is not mixed in the least with materials that could have been derived from the gray till. It antedates the gray till, probably by an interglacial epoch.

The exposures within the Mississippi valley at St. Paul may be reduced to the following general section:

General section of the drift at St. Paul.

1.	Loam,		3–10 feet.
2.	2 (a)	Gray sand, gravel and stones,	0–10 feet.
	2 (b)	Fine laminated blue brick-clay,	0–16 feet.
	2 (c)	Gray sand, gravel and stones,	20 feet.
	2 (d)	Gray till. Seen,	0–2 feet.
3.	3 (a)	Fine, laminated red sand or clay, the tripoli of Stillwater,	0–10 feet.
	3 (b)	Red till, with boulders of crystalline rock,	10–20 feet.

Boulders of northern limestone are found in the drift ridges and knolls about Mudhole and Fitzhugh and Gervais lakes; on sec. 17, near the Hennepin county line, Rose, 4 feet long and 18 inches wide, the surface being a pebbly loam; and on the county line road between Anoka and Ramsey counties, about N. E. ¼ of sec. 6, White Bear, in the midst of a sandy, loamy surface, with no boulders generally visible. Large masses have been found on sec. 7, New Canada, near Walter Boyd's; also on the N. E. ¼ of sec. 8, near the end of lake Gervais, on land of Alexander Ducharme.

The loam. That this deposit, which nearly everywhere forms the immediate surface and constitutes the soil, as already stated, is the result of a widespread diffusion of fresh water, at the time of the last glacial epoch, over those surfaces, either drift-covered or not, which were not at the time affected by the glacier movement, is highly probable, but what the peculiar circumstances and causes of such gentle diffusion of nearly tranquil waters were, has for some years been a subject of earnest investigation. It seems probable that some confusion has arisen by not distinguishing between deposits of different kinds and dates. The sandy surface loam which is here referred to, and which is the latest formed, from whatever cause, is probably of a different age from that which has been denominated a pebbly clay, and which also becomes a clayey loam and forms the immediate surface in some high tracts, as already detailed. It is sandy, or graduates downward into sand, in much of the northern part of the county, particularly in the Rice creek valley, and in some places in the bluffs of the Mississippi below St. Paul. It covers the boulders and gravelly clay of the real drift. It fills some old valleys—indeed is always thicker in valleys than on the uplands. It is occasionlly stratified, and passes into sand below in places where agitated water was abundant enough to have moved such materials before the epoch of the loam. In other cases, and generally, it is placed abruptly immediately over a coarse, gravelly or boulder-bearing stratum.

The clayey loam, sometimes pebbly, which lies on the uplands must have been deposited in more quiet waters, and perhaps in the dammed-up waters of bayous at the time of the glacial epoch, prior to the deposition of the sandy loam. In some places this pebbly loam is red or reddish, and in others it is gray. The Trenton limestone at the top of the bluffs in West St. Paul is overlain by a pebbly, water-deposited, red loam in which are rare stones two or three feet in diameter. The loam is twelve feet thick, and the lowest four feet of the stratum are blue. On going back from the river this loam passes into a genuine stony red till within a few rods, and the whole becomes covered with gravel on which is a black loam. This last loam thickens into a great stratum, constituting a large part of the high drift-bluff which rises 275 feet above the river. But as a loam it is only superficial; at some depth below the soil it becomes yellowish, then reddish and sandy and useful for mortar. The till rises to the general surface about a mile back, but is still everywhere covered by a yellow loam, which makes a good soil and rarely shows a boulder except in the wash-outs and ravines. This yellow loam did not result from decay *in situ* for it is the thickest on the knolls.

Two copper nuggets were found on the south side of White Bear lake near the Washington county line; another in the eastern part of the city of St. Paul,* by Mr. J. H. Kloos, a rounded piece in gravel lying directly on the St. Peter sandstone. Le Sueur is reported by La Harpe to have seen a large mass of native copper at a point four leagues above the mouth of the St. Croix, near the mouth of a small lake; but there is no way to locate this in Ramsey county.

Copper masses in Hennepin county have been found as follows: a piece weighing 78 pounds was found in a cut by the Minneapolis and St. Louis railroad about 13 miles southwest from Minneapolis; a piece weighing about ten pounds was found in the fall of 1874 in grading the streets of Minneapolis; near Dayton a piece as large as a hickory-nut was found on the river bank by James Ream; a piece about the size of a pea, covered with green carbonate, was found by the writer in the midst of gravel thrown from his well on State street, Minneapolis, near the university; Dr. D. D. Owen mentions pieces found "in the vicinity of the falls of St. Anthony."† Several small pieces were obtained from the red till overlying the Trenton limestone on the west side of the Mississippi river about three-fourths of a mile below the mouth of Shingle creek, in April, 1884.

Wells. Good water for all household purposes is obtained in Ramsey county with little effort, in shallow wells that seldom pass through the drift, the majority of them being less than twenty-five feet deep. Throughout the northern portion of the county water is generally found in sand, or below a sandy loam, which also rises to the surface forming the soil and subsoil. The underlying clay is seldom penetrated to any great depth. But in the southern portion common wells more frequently are deeper, and obtain water in gravel after passing through not only the surface loam, but also a greater or less amount of red clay.

MATERIAL RESOURCES.

Timber and fuel. The county is generally clothed with a scant forest growth, but the trees are small. It contains but little timber of any sort suitable for lumber, and it is not much cut for fuel. Farmers cut some and haul it to St. Paul, but the wood fuel of St. Paul is very largely supplied from the "big woods," west of the Mississippi river.

* Tenth annual report, p. 197.

† Report of a geological survey of Wisconsin, Iowa and Minnesota, p. 73.

Building stone. The lowest layers of the Trenton, at St. Paul, have been quarried since the earliest days of the city, and, until within a few years, have furnished the principal material for foundations, piers, stone buildings and all structures built of stone. The original defensive portion of Fort Snelling is built of this limestone. It is seen in the piers of the first highway bridge across the Mississippi at St. Paul, in several of the churches and nearly all the older business blocks. But it has been found that this stone is not a first-class building stone. It separates into sheets along the shaly partings that mark its bedding and that cross the strata in blotches, and becomes unsafe when projecting from cornices or capitals. But when it is protected from the weather it endures much better and is still largely employed for under-ground work and for the lining of walls that are faced with other stone.

The quarries in this stone are on both sides of the Mississippi, and are situated along Fort street, on Dayton's bluff, in West St. Paul, and at adventitious points wherever, throughout the city, any desired excavation encounters the rock. Formerly important quarries were worked a few blocks southeast from the state capitol.

Along the south side of White Bear lake, sec. 32, Grant, Washington county, are exposures of the Trenton, and some of them have been worked for building stone. This rock might be found in the upper slopes of some of the mounds in New Canada, or the southern part of White Bear, in the vicinity of Mud-hole lake, and it would furnish a very useful and valuable building material for walls, because there is a total absence of worked building stone in that part of the county.

Mills and water-powers. In 1877 the following mills were in operatiou in the county, but since the railroads have encroached on the natural course of Phalen's creek and the city water works have diminished its volume, some of them have been abandoned.

The *St. Paul mills.* St. Paul, on Phalen's creek; three run of stone for flour and one for feed; twenty feet fall of water on a turbine wheel; only grind for custom use; owned by Henry Shaber.

The *Brainerd mills*, owned by Thau and Ham; three run for flour and one for feed; also on Phalen's creek, with a turbine that receives a fall of water amouuting to thirty feet; custom and shipping.

The *City mills*, St Paul, owned by Lownsman; two run of stone for flour; 19 fect fall; custom only.

The *North Star mills*, St. Paul, owned by Protz and Braun; three run of stone for custom work; head 19 feet.

The *Union mills*, owned by Wm. Lindeke, St. Paul; four run of stone and 20 feet fall of water.

The last three are run by overshot water-wheels.

The *Reserve mill*, owned by — Conrad, St. Paul, on the Fort Snelling road; only adapted for grinding feed; two run of stone and 20 or 21 feet fall; formerly did flouring.

Brick. Brick are made near the northern city limits of St. Paul, on Rice street, by — St. Germain, who uses the common surface loam, which is yellowish. The product is red and is delivered in St. Paul at $8 to $9.50 per thousand.

Red brick are still made on Dayton's bluff from the red laminated clay, or loam, which forms the surface in the valley in which the yard is located—S. W. ¼ of sec. 33. This establishment is owned by Charles and John Jaeger.

Red brick are also made by Fred Jaeger from clay which is taken from the alluvium of the Mississippi in West St. Paul.

On sec. 32, White Bear, at the east extremity of lake Vadnais are two small yards that turn out good common red brick.

The gray brick clay which is seen in the bluffs at St. Paul in the excavations along Fifth street, lies between deposits of coarse gravel and stones, all water-washed. This clay, which is probably the near equivalent, in age and nature, of the brick clay so extensively used for brick at Minneapolis and Carver, has not been thus employed at St. Paul.

The Minnesota Terra Cotta Lumber company, making great quantities of fire-proofing, get their clay at Chaska. This establishment is in E. St. Paul, near the old Harvester Works.

EARTHWORKS.

On Dayton's bluff are several large mounds, one being about six feet high and 30 or 40 feet across. These mounds may be supposed to be the "burial place" referred to by Jonathan Carver when he tarried with the friendly *Naudowessies* at Carver's cave in 1767.*

At White Bear lake is a large artificial mound about 12 feet high and 35 or 40 feet across. It is close to the shore of the lake, within the village, on lot 2, on the road to Goose lake.

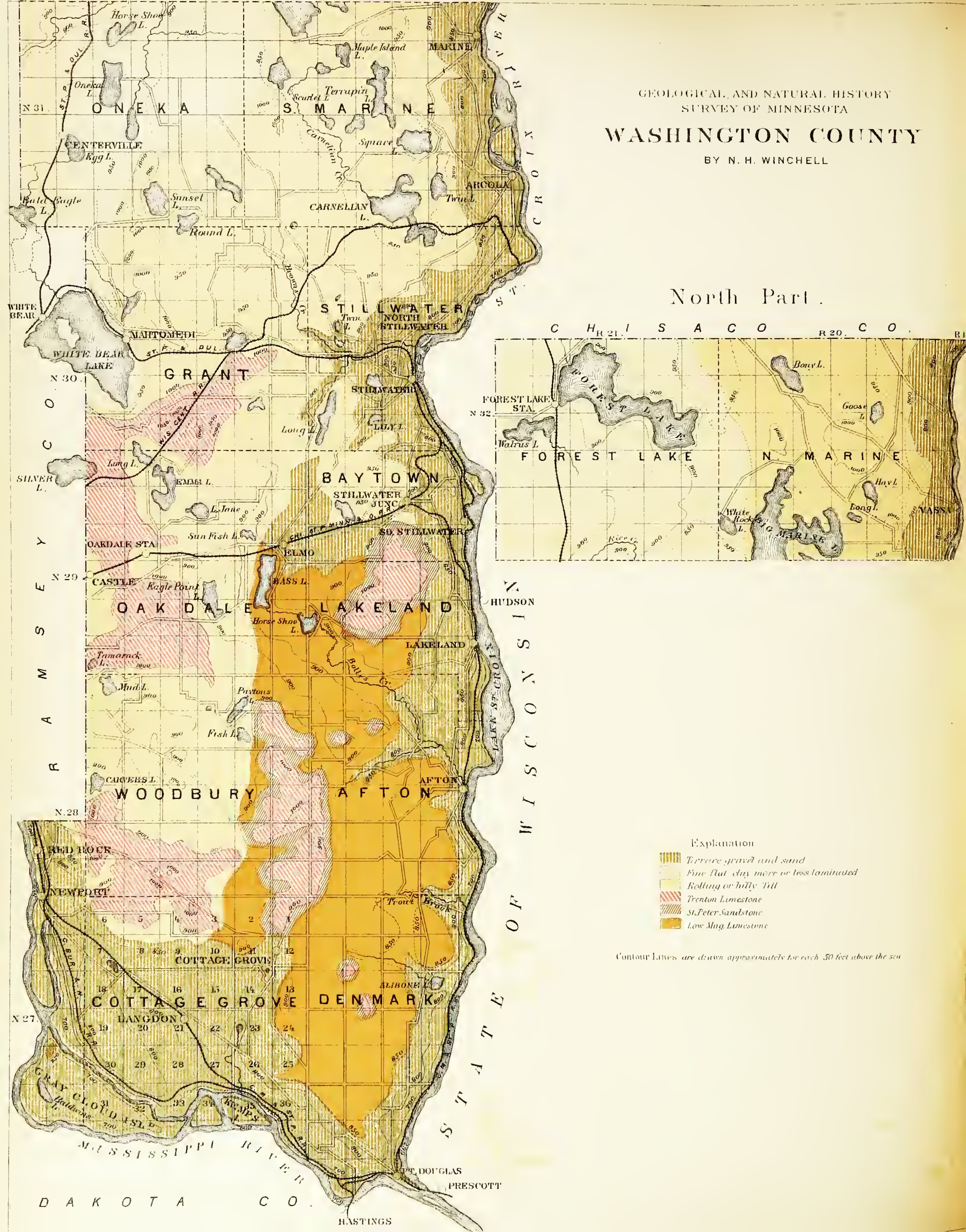
A second cave was discovered in the west face of Dayton's bluff in 1877. It is excavated in the St. Peter sandstone and is probably of natural origin and similar to Carver's cave. It was found in digging to make room for a house and barn at the foot of the bluff. Its extent was not ascertained. It was choked up with a fine, nearly white, tasteless and gritless clay similar to the kaolinic clay that lies on the Cambrian limestones, and in their crevices at Mankato. It seems very probable that this cave, and Carver's cave, date back to pre-Cretaceous age.

* *Travels through the interior parts of North America.* Dublin edition, 1779; p. 60 and p. 80; also p. 376.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

WASHINGTON COUNTY

BY N. H. WINCHELL



CHAPTER XIII.

THE GEOLOGY OF WASHINGTON COUNTY.

BY N. H. WINCHELL.

Situation and area. Washington county is on the eastern border of the state, in the angle formed by the Mississippi and St. Croix rivers. It is uniformly about twelve miles wide east and west, and about thirty-eight miles long north and south, lying through its whole extent on the St. Croix river. The county seat is Stillwater, distant from St. Paul about fifteen miles, in an east-northeast course. Newport, Point Douglas, Afton, Lakeland and Marine are the principal villages.

Washington county contains 430.01 square miles, or 275,205.35 acres, of which 261,675.02 acres are land, and 13,530.33 acres are water.

SURFACE FEATURES.

Natural drainage. The county is mainly drained into the valley of the St. Croix, yet it has no marked water-divide, some of the little streams taking their origin near the St. Croix, in the gravel beds of the drift, and others in some of the lakes near the centre, or west of the centre of the county. White Bear lake and Bald Eagle lake drain westwardly through Rice creek, reaching the Mississippi through Anoka county. The Mississippi and St. Croix rivers are navigable throughout the whole distance that they form the boundary of this county, the latter being widened out into lake St. Croix from Point Douglas, where it joins the Mississippi, northward to the northern limits of the city of Stillwater.

In the northern part of the county are several large and important lakes, notably, Square, Terrapin and Big Marine lakes, which have no visible outlets, except as they discharge into each other, and finally into Carnelian lake, which is nearly two hundred feet above lake St. Croix. Thence their waters seem to pass into the drift deposits and find an underground passage to the St. Croix near Arcola, where a small mill was formerly run by a stream that issues from the river bluff.

Water-power. Bolles creek, which joins the St. Croix at Stillwater, supplies some water-power, which has been improved by the erection of flouring-mills viz.: *Bolles mill,* owned by C. E. Bolles, has a water-fall of 28 feet, with one run of stone which is used only for corn and feed. It has an overshot wheel 26 feet in diameter, with water buckets six feet wide. This is estimated to furnish fifteen horse-power at high water. The same power is used for a wagon-shop and attendant machinery. The *Beehive roller mill* is owned by C. F. Bean. It has seven sets of Livingston rollers, three run of stone, and thirty-two horse-power. In twenty-four hours its capacity is sixty barrels of flour. It has an overshot wheel 32 feet in diameter, under a 34 feet head of water.* The *Reliance mill* is near the mouth of the creek, owned by E. Moench, and has a Leffel wheel 20 inches in diameter, under 36 feet head of water. It has one set of rollers and three run of stone, of which one is for feed. The daily capacity of the Reliance mill is 40 barrels. The *Afton Mills,* said to have been the first flour-mill in Minnesota, is owned by Emil Mœnch. It has three run of stone for flour and one for feed, with a water-head of 11 feet, but with 45 feet available; situated on sec. 15, T. 28—20 W.

At Marine is the *Marine mill,* owned by Ruse and Lohmann. It has a turbine wheel 13½ inches in diameter, the shaft being 60 feet long, supplying 40 horse-power. It is furnished with two pairs of rollers, and four run of stone (one being for feed), which gives a daily capacity of about twenty-five barrels of flour. The little stream which runs this mill rises within the village limits, on the terrace which is underlain by the St. Croix formation, the shedding of the water being due to the shaly and impervious nature of the shales embraced in the rock. The water is unvarying in volume and very cold. It is carried some distance in an artificial conductor and is let fall sixty feet upon the turbine at the mill. This creek increases still more before it reaches the river. At Vasa formerly was a water-power mill run in the same way.

Topography. The tract of rough land which has been described in Ramsey and Dakota counties, extending northeastward from Mendota and Inver Grove, in Dakota county, in which the surface consists of red till, crosses Washington county diagonally. It is from six to ten miles wide. It embraces secs. 3, 4, 5 and 6 in Cottage Grove; the west two-thirds of Woodbury; the west three-fourths of Oakdale; the whole of Grant except a part of secs. 6 and 7; the northeast one-third of Baytown; the whole of Stillwater; the southeast quarter of Oneka and the whole of Marine except a narrow strip along the western side, west of Big Marine lake. This rough tract abounds in short ridges and abrupt hills. Between them are scattered frequent lakes and tamarack swamps. On either side of this rough tract the country is smoother, and on the northwest side it is often flat and wet, the surface waters gathering in grassy swamps which are drained westwardly by tortuous and sluggish streams, the soil being clayey. On the southeastern side the general contour is not so monotonous as on the northwestern side, and there are heavy deposits

* This mill was burned on the night of Oct. 9, 1885.

of gravel and sand filling the drainage courses that extend to the St. Croix valley. The flats in the southeastern portion are due either to the persistence of some rocky stratum, which may occur at different levels, forming benches, or to the even spreading of the water-borne gravel and sand over the plains and the filling of the pre-existing gorges. The surface, furthermore, is overspread with a fertile loam, which constitutes the soil and sometimes is ten or more feet in thickness. Along the Mississippi and the St. Croix these gravel deposits are seen constituting very remarkable and significant terraces, some of the terrace-plains being several miles wide, and rising from 150 to 180 feet above the adjacent water-level of the valley.

The great valley which extends from the northeastern corner of the county round its southern end, from two to three miles wide and about 250 feet below the adjoining uplands, and thence up the Mississippi to the Ramsey county line is, of course, the chief topographic feature of Washington county, and on it, in its relations to the drift, to the stratified rocks and to the geological history of the state and of the northwest, depend all the minor features of the county. These relations cannot be disussed in full here, since they involve facts and principles that include in their scope a much larger area and must be postponed to a later volume of the final report. This valley affords some extensive and very fine landscape scenes, and was the probable route of travel of the first Europeans who visited Minnesota.*

Elevations. The highest land in the county is the range of hills and ridges running northeastward from White Bear lake, which reach 1050 feet above the sea. This consists outwardly of drift materials, disposed in the manner of a terminal moraine, but it is probable that the St. Peter sandstone, if not also the Trenton limestone, is partly the cause of its elevation above the adjoining land on either side, although there is no exposure of these rocks in the county northeast from White Bear lake. Small areas of equal elevation are found southeast from White Bear lake in Oakdale, and here the Trenton limestone is known to exist, the quarry of John Weber being 930 to 950 feet above the sea. It is only a reasonable inference to suppose that this limestone continues northward underlying all the high land as far as the north line of the county, and extending into Chisago county along the east side of the Sunrise river, with some interruption at Lindstrom and Centre City. In

* See vol. 1, p. 5.

Woodbury and Afton, and as far south and east as sec. 17, Denmark, this limestone is seen producing elevated plateaux and isolated ridges, varying from less than a quarter of a mile across to four or five miles, and repeating in every respect the topographic results of erosion that have been described in Fillmore and Goodhue counties.*

The St. Croix river at Osceola, at low water, is 683 feet above average tide; at Marine about 678 feet; at Arcola, 672 feet; and at Stillwater, 667 feet. High-water mark at Stillwater is about 687 feet above the sea. The foot of St. Croix lake, at Point Douglas, is also about 667 feet above the sea. The city datum at Stillwater is 648.94 feet above the sea, referred through the Chicago, Milwaukee and St. Paul railway on the trestle work at Stillwater.

Low water in the Mississippi at Newport is taken at 676 feet; at Point Douglas, 668 feet and at Prescott, 667 feet.

White Bear lake is 920 feet above the sea; Bald Eagle lake is 908. The outlet of White Bear lake is through Bald Eagle lake and Rice creek. Forest lake is 900 feet above the sea and flows to the St. Croix northward through Sunrise river, although there is said to be evidence of a former connection through a valley running southeastward, with Big Marine lake. Carnelian lake is 920.

Elevations on the Chicago, Milwaukee and St. Paul railway.

RIVER DIVISION.

	Miles from Minneapolis.	Feet above the sea.
Newport,	18.1	749.87.
Langdon,	23.5	811.84
St. Croix Junction,	28.9	696.64
Hastings,	29.7	708.31

STILLWATER BRANCH.

	Miles from Stillwater.	Feet above the sea.
Stillwater (on the trestle-work),		696.64
Stillwater, extreme high water of lake St. Croix,		695.14
Stillwater, stage of water July 10, 1881,		684.14
Baytown (or South Stillwater),	3.3	696.64
Lakeland,	8.2	744.64
Afton,	11.1	697.14
Trout brook,	14.4	701.64
Straight cooley,	16.9	702.64
Point Douglas,	22.7	711.64
Junction with the River division,	25.0	696.64

* On Fillmore county see vol. i, p. 270. On Goodhue county see this volume, p. 24.

Elevations on the St. Paul and Duluth railway.

MAIN LINE.

	Miles from St. Paul.	Feet above the sea.
White Bear,	11.9	935
Junction for Stillwater,	12.1	935
Bald Eagle,	13.1	924
Beaver creek (water, 923),	16.9	932
Centerville,	17.2	932
Beaver dam bridge (water, 920),	18	932
Rice creek (water, 913),	20.7	922
Summit (cutting, 5 feet,)	22.1	955
Forest lake station,	25.5	910

BRANCH TO STILLWATER, FROM WHITE BEAR.

	Miles from Junction.	Feet above the sea.
Junction, near White Bear,	.0	938
White Bear (water of lake, 926),	1.3	935
Dellwood,	2	942
Low point in the grade, near Mahtomedi,	2.9	929
Summit of grade (cut, 20 feet),	6.5	984
Summit station,	8.5	919
Brown's creek (bottom, 58),	9.4	867
Brown's creek (bottom, 7),	9.9	853.5
Depot at Stillwater,	11.6	723.0
Stillwater (grade at the lake, on Myrtle street),	12.2	686
Lake St. Croix,	12.2	672.5

Elevations on the Chicago, St. Paul, Minneapolis and Omaha railway.

	Miles from St. Paul.	Feet above the sea.
Tamarack swamp,	6.5	973
Summit, one mile west of Oakdale (cut, 10 feet),	8	1008
Oakdale,	9	979
Lower Bass lake (or lake Elmo),	11.5	886
Upper Bass lake,		900
Lake Elmo station	12	933
East line of Oakdale township,	13	923
Summit, four miles from Stillwater,	15	929
Stillwater Junction (cut, 17 feet),	15.5	887
Bottom of marsh,	17.5	753
Centre of gravel ridge (cut, 50 feet),	17.8	773
Stillwater (high water, 687),	19.0	697

Elevations on the Wisconsin Central railway.

	Miles from St. Croix lake.	Feet above the sea.
Arcola,	2.4	917
Government road,	3	901
Carnelian lake (water, 912),	4.6	920
Highway, sec. 6, 30–20 W.,	7.25	992
Highway, sec. 12, 30–21 W.,	9.25	955
Crossing, St. Paul and Duluth railroad,	11	1017
Summit, sec. 28, 30–21 W.,	13.3	1074
Four Lakes station,	14.6	1005
Long lake (water, 975),	15.2	990
Castle,	16.9	1025
Junction, St. Paul and Duluth railroad,	20.4	938

Elevations on the Chicago, Burlington and Northern railway.

	Miles from St. Paul.	Feet above the sea.
St. Paul (Union depot as per St. Paul and Duluth railway),	.0	704
Pig's Eye bridge,	2.0	707.5
Newport,	7.5	749.8
Quarry,	14.8	699.0
Altenberg cooley,	17.0	695.5
Hastings, bluff crossing (Point Douglas, grade of the Chicago, Milwaukee and St. Paul railway),	19.0	693.9
Point Douglas (highway crossing),	21.0	710.0
St. Croix river (bottom, 652),	21.8	702.4

Average elevation of the county. The estimated average elevation of the townships of Washington county is as follows: Forest Lake, 920 feet above the sea; Marine (north half), 950; Marine (south half), 950; Grant, 940; Stillwater, 900; Oakdale, 950; Baytown, 900; Lakeland, 900; Woodbury, 910; Afton, 910; Newport, 750; Cottage Grove, 800; Denmark, 800. These figures, allowing for the areas which they severally represent, will give an average elevation for the county of about 911 feet.

Soil and timber. The soil in the belt of rough and hilly land, which has been mentioned under the head of *topography*, is that characteristic of the red terminal moraine, which has been more fully described in the report on Dakota county. While the subsoil here is a typical and rather gravelly red till, yet there are patches of more flat or simply undulating contour in which the surface is covered with a loamy soil nearly free from stones. These seem to occur rather irregularly—at least no order or reason for their distribution can be given—but sometimes they seem to be on the margins of the stony till area, and to blend with it by imperceptible degrees of change.

A clayey soil is found covering the marshy flats in Oneka and Forest lake—becoming sandy toward the east, as the surface rises to the hills of the moraine. On the east side of the moraine is found, generally, a lighter soil than on the west side, the surface being a sandy loam, and the subsoil a gravel. Yet, even here, on the most elevated tracts, is found a tight clay-loam, of a yellowish color, which is comparable to that found in similar situations in Dakota and Goodhue counties. This is perhaps of older date than the gravel which fills the valleys, and is perhaps the cotemporary of the fine red stratified clay seen under the river gravels, preserved in some of the angles of the ancient gorges.

This county was originally mostly covered with timber. A few tracts of native prairie were found in southern Lakeland, southeastern Oakdale, eastern Woodbury, Afton, Cottage Grove and Denmark, increasing in amount toward the south. These are all on the eastern side of the morainic belt, and in the southern part of the county. The trees are such as are prevalent in regions covered, in this latitude, with the red till and the modified conditions of it. Black, red and bur oak are common. Poplar and bass are somewhat less common. White oak and elm are not common, though the latter is much more frequent, in company with soft maple, in the river bottoms. The red or river birch (*Betula nigra*) is native on the point, at Point Douglas. Red cedar and white pine are rare along the rocky bluffs. The white cedar, or arbor vitæ, is found sparsely along the St. Croix valley nearly as far south as Stillwater, and hemlock is reported native on both banks of the St. Croix, about three miles above the village of Osceola, Wis. This point on the west side of the St. Croix would be in Chisago county. The trees are said to be small, and one-sided, growing on a rock-bluff. They have not been seen by the writer, and the statement needs verification.

The geological structure.

The St. Lawrence limestone. The only place at which this limestone has been seen in Washington county is at Stillwater. Here it rises about fifteen feet above the level of the railroad grade. It is an impure, greenish limestone, and is seen along the street, near the prison, in layers of two or three inches, but making a firm and persistent wall where it is cut by the street-grade. This limestone is associated with more argillaceous layers, so that much of it would pass for shale. It was from this place that was figured the first specimen of *Dicelocephalus minnesotensis* by Dr. D. D. Owen in his final report, and this species heads the list of organic remains of the "lowest sandstones of Wisconsin and Minnesota," being also figure 1, of plate I of his report. He describes the locality thus: "This species was first found, and is most common, in a dark gray, argillo-calcareous bed intercalated in member *d* of F. 1, ninety or one hundred feet below the base of the Lower Magnesian limestone, near the margin of lake St. Croix, above Stillwater." In other places he refers to this as the *Stillwater trilobite bed.*

*The Jordan sandstone.** Above the foregoing rises, at the same place, a sandstone which develops a thickness of about fifty feet. This is siliceous and nearly uniform in its characters. This sandstone is visible in many places at Stillwater; and in the roads that ascend the bluffs from the valley may be seen very often a small exposure of crumbling white sand belonging to this sandstone, at the distance of a couple of miles away from the lake shore. North from Stillwater this sandstone is used for common building purposes. The quarries are located about a mile above Marine. James Hale has such a quarry at Meridian lake (a part of the main river), and there are several others, less worked, above Hale's.

The main body of the Lower Magnesian limestone is the rock wrought at Stillwater. It causes the principal and most persistent topographic features of the valley, all the way from the Chisago county line to Point Douglas, and it underlies all the western part of the county. It is cut into by the St. Croix valley, and by its numerous tributaries that come into it from the west, the firmness of the rock making the bluffs high and abrupt. These bluffs may be hid by a drift sheet that reaches a thickness sometimes of nearly a hundred feet, but in nearly all places there are sufficient outcrops to warrant the supposition that this limestone is nearly continuous through them. This limestone closely underlies large flat tracts in the central part of the county, viz.: N. W. part of Afton, much of Lakeland, the western portion of Baytown, much of Denmark and Cottage Grove. It is probably the rock that first underlies the drift in the flat tracts of western Grant and Oneka. Within the limits of Stillwater city the 900 foot contour line incloses an area which should have been colored on plate 44, to represent this limestone.

The characters of this stone have been given in the discussion of the building-stones of the state in volume 1, of this report, and have been further elucidated in several of the preceding county reports. It is necessary to add here only such special characters or such new developments as will enable the reader to obtain from the whole a correct estimate of the formation.

At Point Douglas this rock is seen to rise continuously from beneath the water of St. Croix lake to the hight of about one hundred and fifty-five feet above the lake. Above this the alluvial terrace rises about twenty-five feet, or 170 feet above lake St. Croix. About three miles further west the underlying sandstone is seen along the bluff facing the Mississippi, rising about twenty feet above the river. This shows either a fault in the formation or a considerable dip toward the east. This irregularity has been referred to in the report on Dakota county. There is a sudden upward swell in the limestone, both in its lower and its upper surface, running from this point toward the central part of Afton and thence to Hudson. This anticlinal axis can be traced through the central part of Dakota county into the township of Waterford, where it becomes lost in the drift and overlying St. Peter, the Shakopee and Richmond being involved with the main body of magnesian limestone. The change of elevation of the upper surface in Afton amounts to nearly 100 feet. The contour line of one thousand feet in Afton runs over this area, and in eastern Woodbury the same contour includes a part of the area of the Trenton limestone. At the same time the St. Lawrence limestone is reduced in thickness, in the region about a mile and a half southwest from Afton, to forty or fifty feet, due apparently to the destruction of its upper strata.

This irregularity in the Cambrian can be seen most plainly in sec. 30, Afton, where the entire change is compassed within the space of a quarter of a mile, indicating an unconformability of the Silurian upon the Cambrian. The eastern boundary of the Trenton is well identified on the northeast quarter of the northwest quarter of sec. 30. Afton, at the quarry of Mr. E. M. Cox. Immediately east of this is a valley, which contains a small tributary of Bolles creek which passes northward nearly through the centre of the section. In the descent to this valley, from the west, the St. Peter sandstone is exposed. On the east side of the little creek, near the bottom of the ascent toward the east, is an exposure of magnesian limestone at such a level that it must have lain below about forty-five feet of St. Peter sandstone. This would naturally be considered as belonging to the Shakopee limestone (or its equivalent as involved with the main body of the Lower Magnesian limestone) and above it, in the hill toward the east, would regularly be found again the St. Peter sandstone capped by the Trenton at the top. Instead, however, of finding this regular sequence in the eastern bluff of this little creek, higher and higher beds of magnesian limestone, similar to that seen near the level of the creek, are found to extend nearly to the top of the hill, the full ascent being nearly, or quite, as high as the St. Peter-Trenton plateau toward the west, and distant about a quarter of a mile. It seems probable that the upper surface of the "Lower Magnesian" suffered some great erosion before the deposition of the St. Peter sandstone, and whether this accounts for the absence of the Richmond and Shakopee beds in some places, and their presence in others, it is not possible to state unqualifiedly, but it is a reasonable hypothesis.

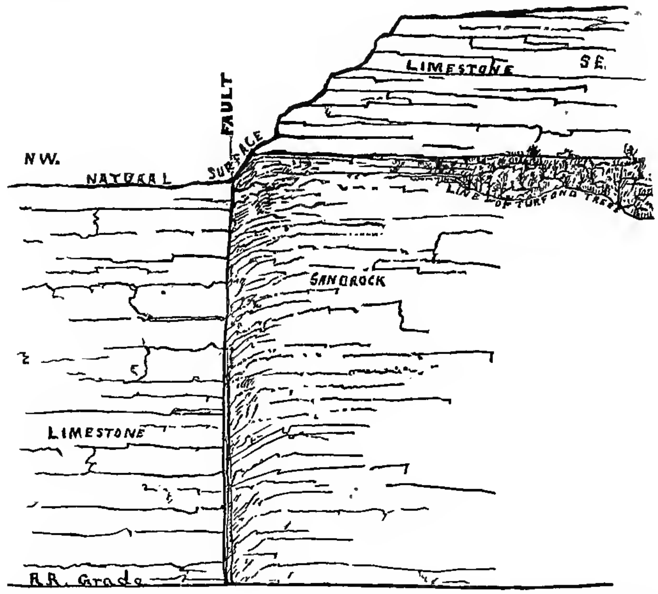


FIG. 28. FAULT IN THE CAMBRIAN NEAR POINT DOUGLAS.

The nature of this irregularity is fully exemplified in the face of the bluff of the Mississippi a short distance above Point Douglas. From the southwestern extremity of the rock bluff, on the Mississippi side, the strata extend northward nearly a mile, without noticeable change. The sandstone that rises above the river amounts to about 60 feet, overlain by 50 feet of limerock. The working necessary for the recent construction of the Chicago, Burlington and Northern railway has freshly exposed the rocks of the bluff all the way from the southern extremity to the point referred to, which is illustrated by figure 28. Here a sudden change takes place. The beds on the up-stream side have been broken, and have gone down from 75–100 feet vertically, so as to bring the limit of the limerock below the river level, and the upper limit 80 feet above it. This fault, which is about half a mile above the crossing of the Chicago, Burlington and Northern and the Chicago, Milwaukee and St. Paul railways, is plainly visible from the trains of either road, and is located about on sec. 7, T. 27–20 W.

The fault, so far as the limestone is concerned, is abrupt, and without selvedge, but the sandrock is shattered for a few feet from the line of present contact, and along the plane of the fracture are some hardened thin sheets of sandrock, about one-half inch to two inches thick, very compact, standing about vertical, parallel with the walls, formed apparently by the cementation of loose sand and fragments that gathered in the open crack since the production of the fault. These hard sheets are revealed by the working of the railroad grade, which has entered the bluff about twenty-five feet, on the south side of the fault, but not on the north, the work of excavation having been stopped by the sudden interposition of the limerock at the same level. This selvedge altogether is from four to six inches thick. On the brink of the bluff this fault makes a perceptible jog in the contour, but back from the bank twenty or thirty rods this jog is not perceptible, but the drift materials fill up the level on the downthrow side to the average hight of the country about. This sudden change in the position of the limestone stratum, which gives a characteristic aspect to the top of the bluff, is very noticeable from the river, looking down stream, below Nininiger.

About twenty rods northwest from this fault, another fault is seen, by which the sandrock appears again above the level of the railroad grade, rising about fifteen feet above the Milwaukee track.* This sandrock, which is the upper portion of the Jordan, contains thin beds of calcareous sandrock, constituting a series of "beds of passage," the introduction of which gives opportunity for the collection of soil and the growth of shrubs and turf; this causes the turfed bed represented in figure 28. In some places this stratum of indefinite character is more calcareous, and could be placed in the Lower Magnesian. It weathers into thin laminæ, sometimes greenish, but above it rises a sheer or overhanging limestone cliff about 50 feet.

The strata continue thus at least to the lower end of Kemp's island, where the Milwaukee road begins to ascend the bluffs. The Burlington road follows the bottomland, and by an occasional cut across spurs of sandrock the continuation of the stratification, without further disturbance, can be traced about a mile further, but it is soon lost to sight beneath the gravel and sand of the valley drift. There is a small area of the magnesian limestone at the north end of Gray Cloud island.

The government quarries are on the west side of the river, at the outlet of Spring lake slough, and the quarry of the Messrs. Lauer is above them. At the former the sandstone shows eighteen feet, being about the same as at Nininger.

* This fault may be the point sketched by Dr. Owen.

Putting together all the facts respecting this irregularity, so far as they are known, there are shown to be three faults, viz: (1) one in the channel of the Mississippi, not seen, between Hastings and the point of the bluff west of Point Douglas, by which the Point Douglas beds are thrown upward. The layers that immediately underlie the village of Point Douglas have the same position as those at Hastings; (2) another by which the beds toward the northwest are dropped again; this fracture is shown in figure 28; and (3) that by which they are again brought to the level of the beds at the S. W. extremity of the point; this is that which was represented by a sketch in the report of Dr. D. D. Owen. The amount of movement, in each case, seems to have been about one hundred feet; and they all occur within a distance of less than two miles.

At Lakeland the top of the magnesian limestone with overlying gravel and loam rises to about nine hundred feet above the level of the sea, or about two hundred and thirty-three feet above lake St. Croix. Its lower portion, and the underlying sandstone, are covered with terrace deposits of the valley. Above this contour line, which marks approximately the extent of the gravel-strewn plains in this part of the county, rises an undulating ascent, occupied by the St. Peter sandstone and the Trenton limestone, amounting in all to about one hundred feet.

At South Stillwater is a break in the continuity of the lake bluff. The high terrace (about eight hundred and seventy-five feet above the sea) which seems to be due, not to alluvial agency, but to the underlying limestone, is disturbed by the little creek, and much till and some rock are, together, the cause of a rough ascent from the level of the town, and the lake, to the upland flat. The Omaha railroad runs down a ravine from the upper flat to the Hudson bridge. This upland flat is from three-fourths of a mile to a mile in width, along here, and descends slightly toward the east. Toward the west it is limited by a more or less timbered belt, the area of the St. Peter, which has a rolling ascent to the Trenton area still further west. This flat occupies the interval between the contours of eight hundred and fifty and nine hundred feet, approximately, and is the northern extension of that at Lakeland. It undulates slightly, or becomes entirely broken — though the broken surfaces are lower, instead of higher, than the flat itself.

At Stillwater the general section of the lake-bluff is as follows:

General section at Stillwater.

1.	Drift-covered slope, from the entrance to Fairview cemetery,	70 feet
2.	Highest exposed beds of the limerock (top of the Shakopee ?), seen at the corner of Burlington and Fourth street south,	15 feet
3.	Slope, mainly hid by drift, but has magnesian limestone in the top; from the level of St. Michael's Catholic church downward,	35 feet
4.	Magnesian limestone, quarried, from the level of the public school house downward,	65 feet
5.	Sandrock, homogeneous, siliceous (Jordan),	50 feet
6.	Impure limestone, and shale (St. Lawrence), seen	15 feet
7.	Sand and shale (?), hid in the debris below the railroad level, extending to the lake,	20 feet
	Total,	270 feet

The total thickness of the limestone, hence, is one hundred and fifteen feet at Stillwater. The quarries are all in the same level, whether in North or South Stillwater. The composition of the slope next above the quarries cannot be made out with certainty. It may contain some sandstone, though it consists of limestone at the top for about ten feet, at least; and so far as the backward working of the quarries exposes it, it consists of limerock. In 1872 some observations and a sketch of the quarry of Hersey, Staples and company, at Stillwater, were recorded, showing interrupted deposits of white sandstone, overlying the quarried strata, and by its disintegration passing through crevices downward and filling irregular pockets still lower in the exposed face of the bluff, but no such phenomena have been seen there since. Such sandstone patches would simulate the beds of sandstone which have been seen in this formation a few miles further east in Wisconsin, and described by Mr. C. L. Wooster* under the name "New Richmond beds;" and it is highly probable that the upper part of the total observed thickness of the rock strata at Stillwater includes both the Shakopee and Richmond, as in the high "Assinniboine bluff" in Goodhue county. The fact that the top of the quarried limerock forms a marked plateau, in North Stillwater, seems to show some natural interruption in the nature of the stratification, causing the more easy destruction and removal of these upper strata, driving them back a quarter of a mile from the strike of the main limestone stratum. The supposed Shakopee here is rather rough, cherty, irregular in grain and stratification, and sometimes is brecciated, at least contains angular pieces recemented. Mr. A. D. Roe has obtained fine specimens of oölyte, apparently from the same beds, in the Brown's creek valley, N. E. ¼ of sec. 20, Stillwater, near the top of the forma-

* Geology of Wisconsin (1873–79), vol. iv, p. 126.

tion. Mr. Roe reports that along the ravine below are seen geodic incrustations of limonite.

The quarries at Stillwater have been described in vol. i, in the chapter on the building stones of the state.

Northward from Stillwater this limestone continues to outline the bluff of the river with more or less distinctness to the north line of the county; but from Arcola northward it lies further back from the river, forming a conspicuous shoulder in the ascent from the river to the uplands, distant nearly a mile from the present water channel. At Marine it is about a mile and a half from the river. Owing to the heavy drift-sheet with which the rocks in this part of the county are covered, no additional details of its nature can be given.

The Richmond sandstone and the Shakopee limestone, so far as they have any known existence in Washington county, have been described in the foregoing account of the main body of limestone.

The St. Peter sandstone has its usual and characteristic development in Washington county, though it seems to be reduced, in some places, to a thickness of less than fifty feet.* It forms, inconjunction with the Trenton limestone, some long ridges and isolated mounds in Woodbury and Afton, which rise about a hundred feet above the surrounding country. There are numerous places where the immediate effect of this sandstone on the surface soil can be seen, although there is no other evidence, except that of the general topography, of its existence. Such sandy and undulating surfaces are found in Oneka and Grant, in a belt of country running just along the west border of the morainic belt already described, and fading out very gradually toward the west and there giving place to the marshes, meadows and lakes which are the reservoirs that feed Rice creek.

The Trenton limestone. Nothing can be added, from notes made in the county, to the known nature of this limestone. As has already been said, it probably runs through the county and extends into Chisago county, but it is deeply covered by drift except in the eastern part of Woodbury and the western part of Afton. The following special notes respecting the quarries in this limestone in the county will give some idea of its distribution and its lithology.

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* If, however, the faults which have been described were formed after the deposit of the Trenton, there is no evidence of its unconformable position on the Cambrian in Minnesota, though such is reported in Wisconsin.

Quarries in the Trenton limestone.

On the west shore of Long lake, S. W. ¼ of sec. 32, Grant, Mr. John Weber owns and works a quarry. This is about six feet above the level of the lake and shows the beds of the Lower Trenton, covered by a heavy stratnm (20 feet) of red till and gravel. The rock is weathered and yellowish, with a blue interior; its upper face not glaciated. There is another small opening in this rock on the west shore of a small lake about a quarter of a mile further north. Neither of these quarries is much worked. Mr. Weber hauls the product of his quarry in winter overland (and over ice) to White Bear and sells at $1.25 per perch, or for 65 cents per perch at the quarry. Another quarry adjoining is owned by Mike Wilder.

Christian Leverer has a quarry near the top of a mound, nearly a hundred feet above the adjoining valley toward the south, on the S. W. ¼ of sec. 9, Lakeland. The beds here are mostly yellowish, but have a blue central portion.

Mr. E. McKean has a quarry, opened in 1845, situated on the S. W. ¼ of the S. W ¼ of sec. 22, Lakeland.

The quarry of E. M. Cox is on the N. W. ¼ of sec. 30, Afton.

Near Newport are the following quarries in the Trenton: C. A. Parker's, S. E. ¼ of sec. 36, Newport; John Willoughby's, N. E. ¼ of sec. 1, Newport; Mrs. Cowell's, N. E. ¼ of sec. 6, Cottage Grove; J. Holton's, sec. 25, Newport. From the last Mr. Holton used to burn quicklime.

Robert Watson, S. E. ¼ sec. 2, Cottage Grove, and Widow Norris, S. W. ¼ of sec. 1, have quarries in the Trenton. The latter is not now worked. L. Holman has one adjoining that of Mr. Watson.

Chas. Metcher has a quarry in the Trenton, sec. 33, Woodbury, and has built his house of it.

THE DRIFT.

The map which is shown by plate 44 exhibits the distribution of the drift in its main features.

The morainic area is rudely coterminous, and coincident in direction with, the known and supposed area of the Trenton-St. Peter plateau. In N. W. Cottage Grove and the S. W. part of Woodbury the surface is rough and the drift abundant and morainic, with much red till and numerous granite boulders. The color is red, and the whole deposit has the characters ascribed to the N. E. till. The region is high, much of it 1000 feet, but it becomes impossible to draw all the contours. When a loam intervenes between the soil and the till the slopes are gentler and longer. The Trenton areas are characterized by white oak, and the St. Peter and Lower Magnesian areas are more apt to have only bur and black oaks. In Oakdale the elevated Trenton plateau, though underlain by till, has a thin sheet of loam, or pebbly clay, and in Grant, soon after leaving White Bear, along the railroad to Stillwater, the country becomes broken and then rolling, with red till mostly. But there is a trace of a gray clay extending as far as five or six miles, nearly to the summit, seen on the tops of the knolls, and probably underlying the lakes and swamps, in the form of a gray pebbly clay, or a very stony clay, or a gray gravel, or even as a gray loam having a definite and constant line of separation from the underlying copper-colored till. It is a trace of a *wash*, and feeble transportation from the glacial field toward the northwest, and is doubtless an extension of the similar deposit seen on the red till between Wyoming and Taylor's Falls, in greater force. The rest of the way to Stillwater is occupied by the red till in rolling contour, until it sinks below the upper level of the gravel terrace of the St. Croix valley. Within the limits of Stillwater, where the surface rises above the general terrace, and the till is exposed, it is thin, and is covered in general by a thin yellowish loam, which sometimes is fine but thick. This red or yellowish loam also covers the red till in Baytown and in the N. W. part of Lakeland. The morainic area in Marine is characterized by long ridges and rounded hills, separated sometimes by tracts of elevated land more nearly flat.

Gravel and sand terraces.

From the north line of the county along the St. Croix valley are strewn remarkable quantities of water-washed drift materials. They are more remarkable for their abundance than along the Mississippi valley. On the eastern side, i. e., in the valley of the St. Croix, these materials at Lakeland reach the hight of 233 feet above the low-water level of lake St. Croix; but they seem there to indicate, not the river bottom but the flood-plain level of the St. Croix river in glacial times. This hight is slightly increased toward the north, and is diminished toward the south. The short section from the Trenton bluff, which rises to over 1000 feet above the sea, near Lakeland, to the level of St Croix lake which is 667 feet above the sea, affords a very good chance to learn the relations of this terrace-flat to the different rock strata that cause bench-levels along the St. Croix valley. Below the Trenton plateau is an undulating, generally timbered, descent, toward Lakeland, over the outcropping edge of the St. Peter sandstone, amounting to about 100 feet; at the foot of this descent a nearly level plain is outstretched which, beginning at about 900 feet altitude, descends to about 850 feet. This plain is probably closely underlain by the Lower Magnesian limerock, although outwardly the surface materials consist of loam and gravel. About two miles below Lakeland some beds that resemble the St. Lawrence appear in this terrace. This level expanse is repeated on the east side of the valley. This plain is succeeded, at Lakeland, by another, which is about forty feet lower and consists almost entirely of gravel and sand. This is cut deeply by streams so that its margin is interrupted by abrupt gullies. It is unquestionably the true alluvial terrace of the valley, and was the bottom of the river when its flood-plain was the upper flat. Below this gravel-terrace plain are some others, less persistent in contour and extension, that seem to have been wrought accidentally here or there as the subsidence of the river progressed, and as obstructions in one place or the other produced or diverted the channel from place to place. The principal one of these lower flats is that on which the village of Lakeland is built.

At Lakeland.

The level of lake St. Croix is 667 feet above the sea.

The depot of the Chicago, Milwaukee and St. Paul railway is 744 feet above the sea.

The gravel terrace of the ancient river rises to 800 feet above the sea, or 133 feet above lake St. Croix.

The ancient flood-plain of the St. Croix ascends from 850 feet to 900 feet above the sea, the latter level being at the outer border of the plain.

The 800-foot contour coincides nearly with the river-ward edge of the ancient alluvial terrace.

The 850-foot contour coincides nearly with the eastern border of the flood-plain or Lower Magnesian terrace.

The 900-foot contour nearly coincides with the upper limit of the flood-plain, and shows what part of the country was submerged when the river was at its highest flood.

The 1000-foot contour is about at the bottom of the Trenton limerock.

The 1050-foot contour would include but a small portion of the upper surface of the Trenton plateau.

The valley of Bolles creek has the ancient high terrace preserved in patches at about the same hight as along St. Croix lake. The sandy plain at Elmo station is an outlying remnant of the upper plains of the Bolles creek valley, and was probably continuous with the terraces of that creek, if not with the terrace of the St. Croix itself, although its elevation is about 938 feet. It was formed, at least, by one of the upper bayous of the glacial waters, and merges into the great Lower Magnesian (or flood) plain which extends southward through Lakeland and Afton.

In the valley of Trout creek, S. E. ¼ of sec. 34, Afton, is a small exposure of fine, red, laminated drift-clay; the same appears also on the south side of the creek, sec. 3, Denmark. It is found also in the valley of Brown's creek, near Stillwater, and has been styled tripoli.

The gravel terrace on which Langdon is located, in Cottage Grove, rises 100 feet by aneroid measurement, above the river at the point where it is exposed by a cut of the Chicago, Burlington and Northern railway, southwest from Langdon. But further from the river it is twenty-five feet higher, by an irregular ascent part of which is in the form of a terrace bench. The flat on which the Chicago, Milwaukee and St. Paul railroad runs, at Langdon, is 812 feet above the sea, and that on which it runs at Newport is 750. In the railroad cut mentioned is exposed a faintly red, stratified drift-clay with undulating stratification. It is mingled with some fine sand interlaminated, and is overlain by a great thickness of gravel-and-sand, which constitutes the greater part of the terrace at this place. It changes to fine sand both above and below and seems to have been made conformably and contemporaneously an integral part of the terrace deposits. The dip of all the strata is about 30° toward the N. E.

The region northwestward from the northwest border of the morainic area, including the northwest part of Marine, Forest Lake and Oneka, is undulating or flat, covered mostly with modified drift or a pebbly gray clay. In some places gravel-and-sand is found, but in general nothing can be seen but a loam, either sandy or clayey, greatly in contrast with the western border of the morainic drift. This kind of drift extends, with a flat surface, west to Centerville, in Anoka county, including the valley of the Rice creek "hay meadows." Sometimes this gray clay, when the loam is removed, is more correctly styled gray till. In the vicinity of White Bear lake, on the north side, this gray till, or pebbly clay, is rather thin, and lies on a red till. In Anoka county this flat extends to the Mississippi, but becomes more and more sandy.

This flat surface seems to characterize the northwest side of the morainic belt. The large lakes which occupy it—Marine, Forest, White Bear, Bald Eagle, Lambert's and probably others in Ramsey county, and the lakes about Centerville in Anoka county—are thus *lakes of the modified drift area.* They seem to have been located by the more rapid retreat of the ice-margin, causing a thinning of the drift, but at the same time spreading further eastward, over the depression thus left in the general surface, a modified condition of the gray till which is here found overlying the red till. Thus the existence and agency of standing, or but slightly agitated, water is recognizable over this tract ever since the glacial epoch, and the present lakes are only the residua from that more extensive bayou. Their surfaces are from fifteen to twenty feet below the surrounding country level.

Copper boulders have been found in Washington county as follows: Mr. Elias McKean, near the north line of sec. 27, Lakeland, found a piece weighing about half a pound in the drift-sand lying on the terrace just below the St. Peter sandstone, when his cellar was dug. Mr. H. B. Vollmer, half a mile further north, also found pieces of pure copper on his farm. Mr. McKean also found a mass weighing eleven pounds at St. Croix falls in 1844, in the rapids of the river above the falls.

In 1881, Mr. Lamoreaux found a piece weighing about two pounds on uncultivated land ("wild land") in Oneka, near Bald Eagle lake. This piece was exhibited to the writer at Minneapolis. It was flat, and from $\frac{1}{3}$ to $\frac{1}{2}$ inch thick, of irregular shape but not ragged.

Other boulders. In the western part of Grant are frequent boulders of a sort of graywacke, and some of them are small, and scattered through the till in a manner somewhat resembling that of Cretaceous shale in Hennepin county. It is of the nature of some of the crystalline slate of the Animikie group as seen near Thomson. Nearly every other sort of crystalline can also be seen, especially trap, gabbro, amygdaloid, iron-banded jasper, granite (red and gray) and mica-schist. Trap and red granite rot easier than the other boulders. A slab of this graywacke, six feet across, was seen nearly on the line between secs. 26 and 25, Grant; near it, gathered from the fields, among other boulders are pieces of white "Winnipeg limestone."

Wells in Washington county.

In the northern part of the county wells are shallow, but in the southern towns, in the immediate vicinity of the preglacial gorges, wells are drilled sometimes over a hundred feet in the underlying rock strata.

Grant. H. Gunderson; S. W. $\frac{1}{4}$ of sec. 16: well, 88 feet, gravel, sand and stony clay throughout; water in sand. Another well four rods northeast from this struck sandrock at the depth of 70 feet.

Oakdale. J. W. Lohman; Lake Elmo station: well, 75 feet; loam and soil, 10 feet; gravel and sand, 60 feet; blue clay, 5 feet (called "fire-clay," possibly kaoline, and the equivalent of that found in the cave at St. Paul; or, instead, the equivalent of that in the Mendota deep well, found beneath the St. Peter sandstone); wells generally about lake Elmo are from 60 to 75 feet deep.

Lakeland. Elias McKean; north line of sec. 27: well, 132 feet; loam, 14 feet; limerock, 118 feet.

Henry B. Vollmer; sec. 22: well, 132 feet; loam, 14 feet; limerock, 118 feet.

John Oliver; sec. 22: well, 132 feet; loam, 14 feet; limerock, 118 feet.

John Schrade; S. E. $\frac{1}{4}$ of sec. 28: well, 142 feet; loam 14 feet; limerock, 128 feet. These are all on the upland terrace which thus is shown to be caused primarily by the rocky formations.

Woodbury. Peter Peterson; N. W. $\frac{1}{4}$ of sec. 13: well, 40 feet; clay and soil, 3 feet; gravel, etc., 21 feet; rock, 16 feet.

Patrick McGuire; S. E. $\frac{1}{4}$ of sec. 30: well, 74 feet; soil and clay, 10 feet; sand, 10 feet; gravel and boulders, 12 feet; stiff, red clay, with no gravel, 5 feet; sand 2 feet, with a little water; boulders and clay, 30–35 feet; hardpan, 4 inches; with water in quicksand.

Most wells on the higher flat of the Trenton obtain water at 16–40 feet, but in the low ground, over the St. Peter sandrock, or on the Lower Magnesian flats, they are often sunk 100 feet more or less.

Afton. George Georgus; N. W. $\frac{1}{4}$ of sec. 6: well, 54 feet; soil and loam, 2 feet; sand, 6 feet; stony red clay, 4 feet; sand, 6 feet; blue clay, 32 feet; sand with water, 6 feet. No opportunity was afforded of seeing this "blue clay." It seems here to have appertained to the drift, and that found in wells at Lake Elmo station may be its equivalent.

William Bohn; S. W. $\frac{1}{4}$ of sec. 6: well 28 feet; soil and loam, 2 feet; gravel, sand and red clay, 28 feet; rock, 8 feet.

Cottage Grove. Wells at Langdon station strike rock at about 20 feet, the materials above being soil and gravel.

H. House; N. W. $\frac{1}{4}$ of sec. 3: well, 34 feet; struck rock. This is situated on the Trenton area.

O. Keene; S. E. $\frac{1}{4}$ of sec. 11: well, 140 feet; soil, 8 to 10 feet; sandrock and limerock, 130 feet.

Peter Thompson; N. W. $\frac{1}{4}$ of sec. 14: well, 129 feet; soil and loam, 4 feet; white sandrock, 125 feet; then hard rock, called "flint rock" by the drillers.

A. Keene; S. W. $\frac{1}{4}$ of sec. 14: well, 129 feet; sand and gravel, with water, 121 feet; boulders, clay, sand, etc., with more water, 8 feet.

R. Bobbins; N. E. $\frac{1}{4}$ of sec. 15: well, 130 feet; gravel and sand, 50 feet; rock, 80 feet.

Denmark. Philip Hammel; N. W. $\frac{1}{4}$ of sec. 9: well, 130 feet; soil, 2 feet; sand, with some thin layers of yellow clay, 128 feet; water was found in sand on top of the rock.

Henry Peterson; N. W. $\frac{1}{4}$ of sec. 17: well, 28 feet; water in limerock.

MATERIAL RESOURCES.

Quarries. The quarries in the Trenton limestone have been mentioned in describing that formation. Those in magnesian limestone at Stillwater have been described, in their main characteristics, in volume one, in the discussion of the building-stones of the state.* These quarries are owned by Messrs. Hersey, Staples and Hall, Fayette Marsh, Esq., and by Dr. Carli. They have long been worked, and they are destined to furnish yet a large amount of very valuable stone.

Tripoli. The bed of tripoli, located at Stillwater, is a part of the drift. It lies below a great mass of drift materials, closely sheltered in a nook between the bluffs of Brown's creek. Its position has preserved it from the erosive action of ice and water. It is of a reddish copper-color, the same as that of the red till which is common in Washington county. Its exposed thickness is about twenty feet, and it is in some places interstratified with thin laminations of quartz sand. It is very fine, and consists of between seventy and eighty per cent of silica. It is so fine that it is nearly impervious, and appears like a laminated clay. This low-lying bed of red siliceous clay is undoubtedly of the same age and nature as that seen south from Langdon, at the railroad cut made by the Chicago, Burlington and Northern railway, and that seen in the banks of Trout creek. Its parallel is also seen in some of the lower cuts in the drift at St. Paul near the level of the Mississippi. It is derived from the natural washing of the red till by streams at the time of high water incident to the glacial epoch, but whether it was at the time of the last ice-age or at some former one it is not yet possible to state.

In 1866 a company was chartered at St. Paul entitled the *Minnesota Tripoli company*, for the purpose of examining and utilizing this substance for purposes of common polishing. From a pamphlet circular† issued by this company the following facts have been obtained: It was thoroughly analyzed at the United States mint, at Philadelphia, by Mr. J. R. Eckfeldt who gave the following statement:

PHILADELPHIA, June. 18, 1866.

GOV. STEPHEN MILLER: Your specimen of tripoli consists of—

Silica,	77.7
Lime,	8.2
Iron,	3.5
Alumina,	3.4
Water, etc.,	7.2

The constituents of tripoli vary from 66 to 90 per cent of silex, according to the different authorities, and is mostly derived, as Ehrenberg has shown, from casts of animalculæ.

J. R ECKFELDT, *Assayer.*

A sample was submitted to Prof. Joseph Henry by senator Ramsey, who made the following statement:

SMITHSONIAN INSTITUTION, Washington, D. C., March 8, 1866.

HON. ALEX. RAMSEY, U. S. Senate: I regret that I have so long delayed answering your letter in regard to the specimen of tripoli, which you submitted for examination. ‡

* Vol. i, p. 159.

† Articles of Association, Assays, Reports and Committees of the Minnesota Tripoli company, St. Paul, 1866. [In the library of the Historical Society.]

‡ A specimen of crude tripoli from the bed of the Minnesota company.

It was placed under the microscope, and compared with the specimen of tripoli which accompanied it;* and also tested by actual application to the polishing of hard substances.

The conclusion arrived at in regard to it is that it is tripoli of good quality.

Very respectfully yours,

JOSEPH HENRY.

NEW YORK, Aug. 15, 1866.

HON. STEPHEN MILLER, St. Paul. *Dear Sir:* We are anxiously awaiting arrival of further specimens of your tripoli. We have a certificate from Messrs. John Rauch & Co., large silversmiths of this city, pronouncing it fully equal, if not superior, to any imported tripoli ever used by them, and they inform us that any quantity of it can be disposed of here at the figures named by you; and have kindly offered to distribute a quantity of samples among their own mercantile friends.

Respectfully your obedient servants,

KEARNEY AND HAWTHORNE.

The following is the report of Charles Upham Sheperd, M. D., professor of natural sciences at Amherst college.

AMHERST COLLEGE, Mass., Oct. 10, 1866.

THE MINNESOTA TRIPOLI COMPANY, St. Paul:

General remarks on the substances denominated tripoli.

The name originated either from the city of Tripoli in Syria, or from the republic of Tripoli in Africa, from both of which places this substance was once obtained.

The most essential characteristics of tripoli are the following: An impalpable texture, softness to the touch, to be easily crushed under pressure of the fingers, opaque, dull (or without even a glimmering lustre), not emitting the clayey or argillaceous odor when breathed upon, easily falling to pieces in water and not forming therewith a pasty mass, without lively colors and generally of a light yellow or ash gray shade, sometimes with a pale tinge of red generally exhibiting an indistinctly slaty structure, as if formed or deposited under water, and finally having a chemical composition into which silica enters in proportions betwixt 60 and 90 per cent, while the other ingredients are chiefly peroxide of iron, carbonate of lime, water and traces of alumina.

The geological origin of tripolies may be various; sometimes being due to the alteration of other rocks by heat, or their permeation by gaseous vapors; at others to the decomposition of particles of iron pyrites diffused through a siliceous rock; and, finally, to lacustrine or river sediment into which the cases or skeletons of microscopic infusorial animals have largely entered. The polishing slate (polierschiefer) of Bilin, Bohemia, is almost entirely made up of the siliceous shells of animalculites of such extreme minuteness, that a cubic inch of the stones contains forty-one thousand millions of individuals.

Uses.

The use of tripolies in the arts is very great. Wherever a high polish is required, whether upon metal, stone, glass, or even wood, their employment is perfectly indispensable, and in very considerable quantity. *The consumption is constantly increasing, and the demand for the article is destined to know no limit.*

Description of locality and specimens of the Minnesota Tripoli company.

The specimens here reported upon (six in number), would appear from statements supplied to me by Isaac Van Etten, Esq., to pertain to a lacustrine or fluviatile formation. The locality is the bed and banks of a stream (Brown's creek) that takes its rise in a pond about two miles from lake St. Croix, the formation commencing at a point about one mile distant from the lake; about half way between the tripoli deposit and the pond is a fall or rapid of 8 or 10 feet over a fine sandstone rock, but below this to the lake no rock appears. The land rises into bluffs fifty feet (50) in hight on either side of the stream, the tripoli coming into view on its bed and banks, for a distance of one-half mile. Its depth has not been ascertained, except at several partial excavations, or exposures of from two to twenty feet, without, however, reaching the bottom of the deposit. Minute shells have been found in the tripoli, none of which were forwarded for my inspection. The presumption concerning them, however, is, that they are lacustrine fresh-water bivalves. The stratum of tripoli upon the banks of the stream is said to be overlaid by decayed vegetable matter to the depth of from one to three feet. Not having seen the formation it is difficult to say whether it belongs to the tertiary, or to the more recent period of the peat-bog formation, though I incline to the latter opinion.

* Specimen of prepared tripoli from Mount Eagle works.

ASSAY OF SIX SPECIMENS PRESENTED.

No. 1. Upper stratum of lower bed. This is slightly the lightest colored of the whole series, being a very light ash-gray, with a faint tinge of red, which becomes more obvious when the substance is powdered. It is also the lightest and most porous of them, as if it had been subjected to less pressure. When unpacked from the paper in which it was wrapped it contained some moisture, with which, however, it rapidly parted on exposure to the sun. On being handled it soiled the fingers more readily than the softest chalk.

Its particles are as fine as flour and impart no sensation between the teeth; however it has nearly the same grit as chemically prepared silica. When breathed upon, it does not give the argillaceous odor of clay. It readily falls to pieces in water through which for a short time it remains suspended, like prepared chalk. On subsiding to the bottom, however, it does not form a pasty mass after the manner of clays. When the clear water has been poured off from the sediment, the latter on drying sets into a firm cake resembling the original material. It lost by heating to full redness, 10 per cent in weight, during which it did not harden. After being pulverized in its original state and sun dried, its loss by ignition was only 2½ per cent. No discoloration or smell was produced by the heating; from which it is apparent that it is free from organic matter. After ignition its color was rather more pinkish.

No. 2. From small shaft at lower bed. Much the same as No. 1, except that its color is more of an ash-gray. It is also more compact, and with a perceptible slaty or laminated structure.

No. 3. A dark seam, one to one and a half inches thick, running through lower bed. This is more like No. 1, only firmer and without any tinge of red until after being heated.

No. 4. From middle of twenty-foot exposures. This seems identical with No. 1, except in being more condensed, as if from pressure. I submitted a specimen of this variety to my friend Dr. Charles T. Jackson of Boston, and he writes me in reply that "a polishing powder exactly like that you send is prepared at the Eagle Mills, in Maine, and sold at twenty-five cents per paper of about half a pound.

No. 5. From water line of twenty-foot exposure. Same as No. 4.

No. 6. From the upper exposure on the creek. Resembles No. 3 with a little more red.

Analysis, in the state of sun-dried powders:

	NOS.					
	1	2	3	4	5	6
Silica,	77.00	82.50	77.00	77.00	77.00	77.50
Carbonate of lime with traces of magnesia,	12.00	7.75	10.75	12.00	11.50	10.75
Peroxide of iron,	7.00	7.50	9.00	8.50	9.00	9.00
Alumina,	1.50					
Water,	2.50	2.25	2.75	2.50	2.50	2.75
	100.00	100.00	100.00	100.00	100.00	100.00

The carbonate of lime (with traces of magnesia) was determined by difference, or loss (after ascertaining the weight of the other ingredients). In making up the 100 parts, the peroxide of iron and alumina were not separated except in No. 1 (but estimated together) as there was evidence that their relative proportion in each of the others was nearly similar.

Conclusions.

It is my opinion that each of these specimens will be found to be good tripoli. That which contains the most silica will be slightly the most efficient. *Neither of them will have to undergo any preparation to be fit for immediate use as polishers.* They may go into commerce as they are, at least after their weight has been reduced six or eight per cent, by pulverization, and sun or kiln drying. They are all equally fine and homogeneous, and possess the requisite of an almost perfectly non-aluminous composition, in consequence of which they will mix freely with water, without becoming clammy or tenacious; the carbonate of lime and oxide of iron are neither in proportions that will be detrimental to their action as polishers inasmuch as both these substances when used apart, are excellent polishers, the first under the denomination of whiting, and the second of colcothar. Experience only can decide the commercial importance of your discovery; but the present examination leads me to predict that it cannot fail of being largely applied to all the various uses of our best tripolies.

Very respectfully yours, C. U. SHEPARD.

Prof. De Montreville, a practical dentist of St. Paul, bears testimony as follows, to the value of this tripoli to the dentist:

DENTAL OFFICE, THIRD STREET, SAINT PAUL, October, 1866.

GEN. VAN ETTEN. *Dear Sir:* I have thoroughly tested the Minnesota tripoli you send me. It is an excellent article, and surpasses the Mount Eagle and other silicated earths heretofore in use in the dental laboratory. As a polisher for the vulcanite work now so much in use, I am persuaded nothing can excel it. The known deposits of this earth (so valuable among the arts) being very limited, I beg to congratulate you on the proprietary of that which must eventuate into a rich pecuniary return, and develop a new branch of wealth in our state. Your obedient servant,

DE MONTREVILLE, M. D., *Dentist.*

Mastodon and man coëxistent in Washington county.

In the fall of 1872 the writer first visited Stillwater, and in company with Mr. Abram Van Vorhes examined the deposit of tripoli in the valley of Brown's creek. At the same time Mr. Van Vorhes pointed out the drift bank in which he had found ancient pottery and the remains of the mastodon. In his presence a sketch was made, and under his direction the position of each was noted on the sketch. An account of this was published in the sixth annual report* (1877). But at that time, as the association of these remains in the drift deposits—or even the existence of human remains in the drift deposits—had not been authenticated, the writer distrusted his own notes, and made a fresh application to Mr. Van Vorhes for the particulars as to their exact position; and although he knew nothing of the position and stratigraphic relations indicated on the sketch made in 1872, the communication of Mr. Van Vorhes in 1877 corresponds with and confirms the description and sketch of 1872.** The nature of the drift-bluff, which is similar to what may be seen at a great many places along the St. Croix valley wherever the terrace gravels are exposed perpendicularly, is shown by the following description:

* Loc. cit. p. 61.

** Following is the communication of Mr. Van Vorhes, giving the details of the description:

STILLWATER, April 26, 1877.

DEAR SIR: Yours of the 16th came duly to hand, and found me almost helpless with a rheumatic attack, which explains my seeming neglect to answer your inquiry.

The mastodon tusks were found about eight or ten feet above the base of the hill; the hill at this point rises at an angle of about 45 degrees. After excavating in the base of the hill on the grade of Myrtle street about 37 feet, the tusks were found, consequently 37 feet below the surface; at this point the hill was about 90 feet high.

The crockery (pottery, N. H. W.) I found some thirty feet further into the hill, and some six or eight feet higher in the strata. This hill is a continuous tongue of land lying between the Florence mill stream and a spring run. The two streams run parallel and some 350 feet apart. The hill is so steep on the Florence mill side as to be inaccessible except by clinging to roots and brush growing on it. The material at the base is sand and small gravel. Where the tusks were found the strata were pure sand ten or twelve feet thick exhibiting clearly the direction of the current in an eastward inclination one or two degrees. On the top of the hill were heavy boulders of the drift period. I deeply regret that indisposition and the weight of eighty-four years have rendered me incapable of composing a satisfactory communication.

Yours, with much esteem, A. VAN VORHES.

Drift section at Stillwater containing human and mastodon remains.

1.	Disturbed sand, with some boulders,	5 feet
2.	Fine sand, with nearly horizontal strata,	2–6 feet
3.	Gravel and boulders,	0–4 feet
4.	Very fine, handsome sand, in horizontal stratification,	15 feet
5.	Coarse gravel and boulders,	4–6 feet
6.	Horizontal strata of fine sand,	30–40 feet
7.	The tripoli bed lies next below this fine sand.	

The tusk was found in No. 6, and near the bottom, but about 37 feet horizontally from the natural slope of the bluff which was being graded for street purposes. The pottery was in the same stratum but about 30 feet further in the hill and six or eight feet higher in the deposits. The specimens were preserved in the collection of the St. Paul academy of sciences in 1872, but have been destroyed since by fire. Mr. Van Vorhes was a well known and experienced surveyor, and an exact observer, and there is no reason to doubt the veracity and the correctness of his descriptions. But there is lacking, in this case, as in numerous others that have been published within the last twenty years, the confirmation of a competent geological observer. It is probable that these articles of human manufacture were found as described, and were included in the drift-gravel as native and constituent portions of it, but it cannot be denied that it is possible that the observers saw them only after they had fallen from above along with a quantity of dislodged materials, and that in their true positions they were quite superficial and recent.

It should be understood that the date of these remains, if not modern, is that of the river-gravels, and hence that they can be assigned to no earlier a period than the last glacial epoch, or not earlier than about ten thousand years ago. The reader is referred to the discussion of the recession of the falls of St. Anthony in chapter eleven. There are indications, in the existence of what may be considered interglacial vegetation, beneath the valley deposits in the vicinity of Stillwater, that the St. Croix gorge dates far back in antiquity, and there are other indications that it was probably the first portion of the Mississippi valley to take place and shape as an avenue of drainage from the palæozoic continent to the surrounding palæozoic ocean.*

At Red Rock, the rock itself is a boulder of granite, originally light-colored, but stained with the Indian's "red paint," and more recently girdled by successive belts of bright vermilion with oil and lead. On the end lying away from the river is a representation of an Indian's head surmounted by eagle's feathers. It lies within thirty-five or forty feet of the river and on an outcropping ledge of Shakopee limestone which is exposed in the river-bank immediately below, rising from ten to fifteen feet above the water.

* Compare the sixth annual report, p. 85.


GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
CHISAGO, ISANTI AND ANOKA COUNTIES
BY WARREN UPHAM.
Explanation.
Recent — Alluvium.
Glacial — Modified Drift, flat or undulating.
Modified Drift, rolling or kame-like.
Till, undulating or flat.
Till, more prominently rolling
Till, knolly and hilly; Terminal Moraines.
Silurian — Trenton limestone.
Cambrian — Lower Magnesian limestone.
St. Croix sandstone
Copper-bearing trap and conglomerate
Contour Lines are shown approximately for each 50 feet above the sea.
KANABEC COUNTY
PINE COUNTY
WISCONSIN
SAINT CROIX RIVER
MILLE LACS COUNTY
SHERBURNE COUNTY
HENNEPIN COUNTY
MISSISSIPPI RIVER
RAMSEY COUNTY
WASHINGTON CO.
ISANTI
CHISAGO
ANOKA
MAPLE RIDGE
STANCHFIELD
NESSEL
RUSHSEBA
WYANETT
SPRINGVALE
CAMBRIDGE
FISH LAKE
SUNRISE
AMADOR
SPENCER BROOK
BRADFORD
NORTH BRANCH
BRANCH
STANFORD
ATHENS
OXFORD
LENT
CHISAGO LAKE
SHAFER
SAINT FRANCIS
LINWOOD
BETHEL
BURNS
OAK GROVE
WYOMING
FRANCONIA
COLUMBUS
RAMSEY
GROW
HAM LAKE
BLAINE
CENTERVILLE
FRIDLEY
TAYLORS FALLS
CENTER CITY
OSCEOLA
RUSH CITY
HARRIS
STACY
LINDSTROM
DEER GARDEN
COON CREEK
DAYTON
ITASCA

CHAPTER XIV.

THE GEOLOGY OF CHISAGO, ISANTI AND ANOKA COUNTIES.

BY WARREN UPHAM.

Situation and area. These counties (plate 45) lie in eastern Minnesota, close north of Saint Paul and Minneapolis, and between the Mississippi and St. Croix rivers, together forming a district whose extreme extent from north to south is 48 miles and from east to west about 42½ miles. The Mississippi is the southwest boundary of Anoka county, and the St. Croix river separates Chisago county from the state of Wisconsin. The largest towns are Taylor's Falls and Rush City in Chisago county, Cambridge in Isanti county, and Anoka in the county of the same name.

The area of these counties, in square miles, is as follows:

	Land.	Water.	Total.
Chisago,	421.02	30.64	451.66
Isanti,	416.61	41.24	457.85
Anoka,	424.88	20.10	444.98

SURFACE FEATURES.

Natural drainage. Rum river, the outlet of Mille Lacs, enters Isanti county near the middle of its west side, flows eastward to the centre of this county and thence southward, passing through western Anoka county, to its junction with the Mississippi at Anoka. Nearly all of Isanti county and more than half of Anoka county are drained by this stream. Its most considerable tributaries from the west in this district are Spencer brook, Seely creek and Ford or Trott brook; and from the north and east the Upper and Lower Stanchfield creeks and Cedar creek.

Coon and Rice creeks join the Mississippi southeast of Anoka; the former drains the central part of Anoka county, and the latter its southeast part, besides a portion of Ramsey county. Manomin, the former name of Fridley township, in which Rice creek reaches the Mississippi, is the Chippewa name of this stream and of the wild or Indian rice (*Zizania aquatica*, L.), which grows luxuriantly in the lakes along its course.

The tributaries of the St. Croix river in Chisago county are Rock, Rush and Goose creeks and Sunrise river. The latter drains the greater part of southern Chisago county, besides a tract in southeastern Isanti and the northeast corner of Anoka county.

Lakes. Each of these counties has numerous lakes from a half mile to one or two miles in extent. Chisago county contains several of greater size, namely, Rush lake, about eight miles long, very crooked, with several islands, at the head of Rush creek; Goose lake, three miles long from north to south, in the line of continuation of the west part of Rush lake; and the Chisago lakes and Green lake, which, with Sunrise lake and about a dozen others of small extent, make up a notable group, attractive by their scenery, fish and water-fowl, lying between Wyoming and Taylor's Falls.

Another cluster of lakes, numbering seven between a half mile and one and a half miles long, is situated in Centerville, Anoka county. Rice creek flows through five of these lakes. In the northeast part of this county and the southeast corner of Isanti, a series numbering about fifteen, of which the largest are Linwood and Coon lakes, reaches eighteen miles from northeast to southwest.

Topography. The greater part of this district is an approximately level plain of gravel and sand, belonging to the modified drift. Some portions of this tract are slightly or moderately undulating or rolling, with the elevations 10 to 25 feet or rarely more above the depressions and lakes; but it is mainly almost level, with the sloughs and lakes only 5 to 15 feet lower than the general surface. Several considerable areas, not included in this tract of modified drift, remain to be described in the ensuing paragraphs.

A belt of morainic till extends across Maple Ridge and Stanchfield, the northern tier of townships in Isanti county, and Nessel, the most northwestern township of Chisago county, having a prominently rolling or hilly contour, with the greatest hights 40 to 75 feet above the hollows and lakes. About Rush City, in Rushseba township, the most northeastern of Chisago county, the contour is again a level plain, but its material is till, which thence continues northeastward with the same level surface to Snake river in Pine county. Southwest from Rush City, Fish Lake, the north and west portions of North Branch, and the east third of Isanti township, are moderately undulating till, with the surface in swells and short smooth ridges 10 to 25 feet in hight.

In southeastern Chisago county a more or less morainic tract of till extends from the Sunrise river east to the St. Croix. The swells and hills here are elevated 40 to 60 feet above the streams and the plentiful lakes.

The east half of Centerville, in the southeast corner of Anoka county, is also till, but it is nearly level or only moderately undulating. In the southeast part of Fridley morainic till rises in irregular hills 200 feet above the Mississippi river.

Again, on the west side of Anoka county, morainic till forms the surface in the northwest part of Ramsey, in northwestern Burns, and the western third of St. Francis, having a rolling or moderately hilly contour. This tract continues north into the southwest part of Stanford in Isanti county, and west into Sherburne county, there including the massive morainic hills north of Elk River.

The channels worn by creeks and rivers in their course across the area of modified drift are mostly 20 or 30 feet below the general surface; and this plain through Anoka county is only 50 to 75 feet higher than the Mississippi river. A deeper valley has been eroded by the St. Croix river, which flows about 140 feet below the level of the plain of till at Rush City, and 250 feet below the rolling surface of till that extends westward from this valley in the southeast part of Chisago county, while the tract of modified drift extending through the centre of this county is from 75 to 150 feet above the St. Croix at the mouth of Sunrise river.

Elevations, Saint Paul & Duluth railroad, in Chisago county.

From profiles in the office of H. A. Swenson, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Wyoming	29.8	896
South branch of Sunrise river, water, 876; grade	30.0	893
Middle branch of Sunrise river, water, 875; grade	33.7	888
Stacy	33.9	893
North Branch	41.8	894
North branch of Sunrise river, water, 862; grade	42.1	888
Harris	46.9	895
Goose creek, water, 865; grade	47.1	891
Rush creek, water, 895; grade	53.6	916
Rush City	53.8	916
Balsam creek, near the north line of Chisago county, water, 926; grade	57.0	931

Branch from Wyoming to Taylor's Falls.

	Miles from Saint Paul.	Feet above the sea.
Junction near Wyoming, about a sixth of a mile south of the depot	29.65	898
Summit, natural surface, 909; grade	30.40	903
Sunrise river, water, 875; grade	31.50	880
Summit, natural surface and grade	33.6	922
Chisago City	36.0	917
Trestle bridge over Chisago lake, water, 896; grade	38.4	928
Lindstrom	38.6	932
Summit, natural surface and grade	39.1	937

	Miles from Saint Paul.	Feet above the sea.
Chisago lake, water, 896; grade	40.2	901
Center City	40.3	901
Summit, natural surface, 950; grade	42.6	946
Siding	43.8	937
Franconia	45.8	915
Lawrence creek, water, 861; grade	46.3	801
Cuts in sandstone, top of sandstone 856 to 861; grade	47.8 to 48.2	855 to 832
Cut in trap-rock top of rock 823; grade	48.8 to 48.9	802 to 797
Taylor's Falls, passenger depot	49.1	791
Taylor's Falls, freight depot and yard	49.9	750

Branch from Rush City to Grantsburgh, Wis.

	Miles from Saint Paul.	Feet above the sea.
Junction near Rush City, about a fifth of a mile south of the depot	53.6	916
Rush Creek, water, 841; grade	56.3	849
St. Croix river, water, 775; grade	58.6	705
Summit, natural surface and grade	69.1	921
Grantsburgh	70.2	895

Elevations, Saint Paul, Minneapolis & Manitoba railway, in Anoka county.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Fridley	17.0	848
Rice creek, water, 821; grade	17.2	847
Coon creek, water, 832; grade	21.7	858
Anoka	27.6	883
Rum river, water, 845; grade	28.2	866
Itasca	34.0	891

The following elevations of the Mississippi and St. Croix rivers, in the ordinary stage of water, have been determined by the United States engineer corps, under the direction of Capt. C. J. Allen:

Mississippi river.

	Feet above the sea.
At Dayton and the west line of Anoka county	843
At Anoka	829
At the mouth of Rice creek	804
In Minneapolis, above the falls of St. Anthony	802

St. Croix river.

	Feet above the sea.
At Rush City ferry	772
At the mouth of Sunrise river	758
At the mouth of Trade river, about five miles farther east	753
At the mouth of Rock creek, three miles north of Taylor's Falls	726
At Taylor's Falls, lower steamboat landing	687
At the head of Rock island	685
At Osceola, three miles south of Franconia	683

The morainic hills north and west of Rush lake, which are 1,000 to 1,050 feet above the sea-level, form the highest land in Chisago county; and its lowest land, the shore of the St. Croix river below Taylor's Falls, is 690 to 680 feet above the same level. Estimates of the average hights of the townships of this county are as follows: Nessel, 1,000 feet above the sea; Rushseba, 910; Fish Lake, 975; Sunrise, 860; Branch, 890; Amador, 875; Lent, 890; Wyoming, 910; Chisago Lake, 925; Shafer, 910; Taylor's Falls, 825; and Franconia, 880. The mean elevation of Chisago county, derived from these estimates, is 915 feet above the sea.

Along the railroad from Wyoming to Taylor's Falls, the country is nearly flat or slightly undulating to Lindstrom, after passing which the road soon descends to a lake region, in gray till. This extends to and slightly beyond Center City. The gray till at Center City lies on a fine and stratified red sand which seems to have been derived from the northeast. In the rolling tract one mile east of Center City, boulders are seen gathered in piles in the meadows. This gray till is not very coarsely stony. It is rather pebbly, taken altogether. Many of the boulders are of light granite, but the clay has many limestone pebbles, and often graduates upward into a loam which makes a fine soil for farming. At about four miles east of Center City the surface becomes flat again with evidence of stones and gravel from the northeast—particularly of rusty sandrock—though the till is still gray, or is blotched by red and gray, with a preponderance of the characters of the gray. At Franconia station the same characters still remain; and they continue to the St. Croix bluff, where the upper stratum in the drift cuts is gray till of varying thickness, reaching 25 feet and containing pieces of northern limestone, and lying on red sand and gravel. The last changes locally to red till and increases in amount. [N. H. W.]

The highest land of Isanti county is in Maple Ridge and the northwest part of Wyanett, about 1,100 feet above the sea; and its lowest point is probably where the North branch of Sunrise river crosses the east line of North Branch township, about 875 feet above the sea. The descent of Rum river in this county is 75 or perhaps 100 feet, from nearly 1,000 feet at its west line to about 900 feet above sea-level where it enters Anoka county. Estimates of the average hights of the townships of Isanti county are as follows: Maple Ridge, 1,060; Stanchfield, 1,025; Wyanett, 1,050; Spring Vale' 1,025; Cambridge, 1,000; Spencer Brook, 1,025; Bradford, 1,000; Isanti, 980; North Branch, 960; Stanford, 980; Athens, 950; and Oxford, 925. The mean elevation of Isanti county, according to these estimates, is approximately 1,007 feet above the sea.

The highest land of Anoka county is about 1,000 feet above the sea, this being the elevation of the morainic hills in the east edge of sections 24 and 25, Fridley, and also of a part of St. Francis and Burns, in the northwest corner of the county. The greater part of its area is nearly level, with an elevation that differs but little from 900 feet. Its lowest land, the shore of the Mississippi river at the line between Fridley and Minneapolis, is 802 feet. The Rum river descends about 70 feet in this county, its mouth being 829 feet above the sea. The average hights of the townships are approximately as follows: Linwood, Columbus, Centerville, Bethel, Ham Lake, Blaine, and Oak Grove, 900 to 920 feet; St. Francis, 950; Burns, 960; Ramsey, 910; Grow, 890; Anoka, 875; and Fridley, 875. The mean elevation of Anoka county is about 910 feet.

Soil and timber. The extensive deposit of modified drift in these counties has generally a black soil six inches to a foot thick, beneath which the subsoil is yellow gravel and sand. This area is more productive than would be at first supposed from an examination of its subsoil and from its usual covering of bushes and small scattering oaks, commonly known as "oak openings." The wood cut from this land fully pays the cost of grubbing up the stumps and roots to make it ready for plowing, and its yield of wheat is fifteen or often twenty bushels per acre. This sandy land is specially adapted for the early and successful growth of garden produce, as vegetables and berries, for which Minneapolis and Saint Paul afford a near market. Many of the sloughs now bearing marsh grass or tamaracks are well suited for cranberry culture, which, however, require much expense in preparation before the first crop, but very amply repay this with profit in a few years. The areas of till have a clayey soil and subsoil and usually bear more and larger trees. Under cultivation the till possesses more enduring fertility than the modified drift, but both soon show some decline and are improved by manuring and rotation of crops.

The whole area of these counties was originally wooded, excepting grassy sloughs or marshes of small extent, and a few limited tracts of prairie, seldom a mile wide, beside the Mississippi river. The principal species of trees are black and bur oaks, ironwood, white, red and rock elms, hackberry, the common aspen or poplar, large-toothed poplar and balsam poplar, basswood, sugar and silver maples, box-elder, wild plum, black cherry, Juneberry, black and white ash, butternut, bitternut, yellow birch, paper or canoe birch, and tamarack. Red cedar and cottonwood are infrequent, occurring mostly on bluffs of streams and borders of lakes.

White pine reaches its general southern limit in the north edge of Isanti and Chisago counties, but isolated trees of this species occur rarely on the bluffs of the Mississippi river, as at Dayton, and a considerable growth of it is found on the St. Croix river at Taylor's Falls and in Franconia. It was first cut for lumber in this state, at least in any noteworthy amount, on Lawrence creek in Franconia, a small tributary of the St. Croix. Red or Norway pine, jack pine and black spruce also occur sparingly in northern Isanti and Chisago counties, coinciding nearly with the white pine as to their southward limits.*

The common shrubs include hazelnut and dwarf oaks, prickly ash, stag-horn and smooth sumacs, frost grape, Virginian creeper, climbing bitter-sweet, wild red cherry and choke-cherry, red and black raspberry, high blackberry, wild rose, prickly and smooth wild gooseberries, black currant, species of cornel or dogwood, wolfberry, sweet viburnum or sheep-berry, high or bush cran-berry, speckled or hoary alder, and several species of willow.

GEOLOGICAL STRUCTURE.

Outcrops of the formations underlying the drift are found in this district only along the St. Croix river, and in the south edge of Fridley, Anoka county, close to the Mississippi river. Cupriferous trappean rocks probably belonging to the early part of the Potsdam period appear at Taylor's Falls, and, abutting with level stratification against them, the sandstone and shales of the St. Croix epoch in the early part of the Calciferous period. The St. Croix sandstone is again seen at several places in the north part of Chisago county, on the St. Croix river and on Rush creek. At the southeast corner of this county, in Franconia and Osceola, the St. Croix bluffs contain also the next overlying formation of Lower Magnesian limestone. All these belong to the Cambrian age, the earliest grand division of Palæozoic time. The outcrop in Fridley is Trenton limestone, of the next succeeding Silurian age. The description of these rocks is given in their chronologic order, followed by that of the glacial and modified drift, which belongs to the very latest completed period of geologic history.

* The following trees were noted growing native at Taylor's Falls: white oak, aspen, bur oak, black oak, soft maple, bitter-nut, sugar maple, great-toothed poplar, white birch, white pine, red cedar, white elm, butternut, black cherry, white ash, black ash, red elm, tamarack, gray birch, bass, water beech, ironwood, thorn apple, Norway pine, and at two miles below Franconia, white cedar and cottonwood. Large trees of balm of Gilead grow in the yards, but are not certainly native. [N. H. W.]

Copper-bearing trap. The remarkable outcrops of trappean rocks forming the picturesque and grand Dalles of the St. Croix are some thirty miles south of the areas of these rocks on the St. Croix, Kettle and Snake rivers in Pine county. About a mile above Taylor's Falls and close above St. Croix falls, trap occurs in the channel and on both sides of the river, its highest portions having an elevation of 50 feet. At Taylor's Falls the St. Croix river enters its Upper Dalles, where for three-fourths of a mile it is walled on both sides by bold, often vertical, ragged cliffs, 75 to 150 feet high, of tough, nearly black, massive trap. This gorge and the similar one of the Lower Dalles, about a quarter of a mile long, close above Franconia, have been cut in this rock by the river, the excavation being aided by nearly vertical joints. At Taylor's Falls steamboat-landing these bear N. 60° E. and N. 45° W.

East of the road to this landing, the ledges of very hard trap, 25 to 60 feet above the river, are surprisingly water-worn, with many pot-holes of all sizes from those only one and a half feet in diameter and six feet or more in depth, almost perfectly cylindrical, to the caldron, situated six rods northeast of the landing, twenty feet in diameter, circular, and ten feet deep with perpendicular sides to the surface of the water that partly fills it. Into one of these wells, eight feet in diameter, a pole has been thrust down thirty feet.

The origin of this formation, as in Pine county and in the lake Superior region, appears to have been by overflows of molten rock poured out from fissures of the earth's crust. Only inconsiderable portions of the beds exposed here are amygdaloidal, and this structure is rarely seen to be characteristic of distinct layers. A general system of jointage planes, which is quite noticeable in these outcrops, dipping about 15° W. by S., is regarded by Prof. T. C. Chamberlin as parallel with the planes of bedding of the trappean overflows, at first nearly level, but subsequently disturbed and tilted. He further remarks that these rocks and those of Pine county are bent in a synclinal, like their broader continuation northward, which forms the depression of lake Superior; and that this continuously synclinal belt is slightly curved upward, saddle-like, between the lake and its southern extremity in the St. Croix basin.

A band of conglomerate, the only one observed in the exposures of trap in this region of the Dalles, is reported by Mr. D. A. Caneday, in a ravine on the Minnesota side, nearly a mile southwest from the bridge; being a layer eight feet thick, dipping 15° westerly, overlain and underlain by trap, which is dark above and reddish beneath.

Exploration for copper and silver has been made in the trap formation at Taylor's Falls by three shafts. A short distance east of the Lutheran church on the road to Franconia, Mr. N. C. D. Taylor went to a depth of 43 feet, finding films and small masses of native copper. This is near the highest part of these trappean ledges, about 200 feet above the river, and 50 feet below the average hight of the rolling drift which universally covers the bed-rocks from the top of this river-bluff westward. The two other shafts were sunk by the Taylor's Falls Mining Company, one being near the river, and the other about 75 feet above it, on Ravine street. The last was worked in 1874 and 1875, and reached a depth of 120 feet, following a vein eight to ten feet wide, which dipped to the west about 85°, or ten feet away from a plumb-line. This vein contained ores of both copper and silver. An apparently metalliferous vein, four feet wide, with strike nearly from north to south, is seen on the surface about half-way between this and Mr. Taylor's shaft. Another, eighteen inches in thickness, dipping 12° W. S. W., is described by Mr. Caneday, near the foot of the Upper Dalles, at a little hight above the river; the four inches next to the hanging wall being bornite, a sulphuret of copper and iron, with about a foot of white quartz and a thin earthy layer below.

St. Croix sandstone. At Baltimore rapids, on the St. Croix river a little below the northeast corner of Chisago county, in the N. E. ¼ of section 4, Rushseba, the St. Croix sandstone forms a bluff on the Minnesota side, 50 feet high and a quarter of a mile long.

In the southwest quarter of this section, about a half mile below the last, ledges of sandstone, light gray in color, coarse-grained and rarely including white quartz pebbles up to three-fourths of an inch in diameter, friable, and level in stratification, occur at two or three points within an eighth of a mile on the Wisconsin side, rising 10 to 15 feet above the river.

An eighth of a mile farther southwest, the same stone rises on the Minnesota side in a vertical and overhanging cliff twenty feet high and about fifteen rods long, known as the "big rock." It is the last prominent ledge seen in descending the St. Croix before coming to the high outcrops of trap in the southeast part of this county.

Only two localities of rock-exposures are known in the intervening distance of twenty-five miles, both being sandstone with the characters already described. These are at a fall of about ten feet on Rush creek a half mile above its mouth, and at Yellow Pine rapids in the St. Croix, on the east side of section 18, Sunrise, where low ledges of this stone are seen in its channel and banks along a distance of nearly a mile.

The sandstone and its included shales are exposed at many places in the bluffs of the St. Croix river at St. Croix Falls and Taylor's Falls, and through Franconia. In stratification all these beds are nearly horizontal and show no indications of any disturbance or metamorphism since their deposition. They reach from the level of the river to hights 50 to 100 feet above it, and are overlain by the glacial drift. Where they lie in contact with the steep, vertical, or overhanging sides of the trap rocks which here form the Dalles of the St. Croix, they are often changed to conglomerate, containing many fragments that fell from these cliffs, which had already been deeply eroded before the St. Croix sandstone and shales were deposited. These sediments contain multitudes of shells of *Lingula and Orbicula* species, and trilobites occur rarely.

At St. Croix Falls, in Wisconsin, fossiliferous shales, mostly gray, but in some beds green, often bearing films of iron rust in their crevices and joints, and including thin layers of sandstone, are seen from the river's shore to a hight of 50 feet. These shales also form the Minnesota bank of the river, about 30 feet high, between twenty and forty rods north of the Taylor's Falls bridge.

In the two miles between the Upper and Lower Dalles, the formation is a whitish or yellowish gray, soft, often friable, sandstone, exposed in the bluffs west of the St. Croix to the hight of about 100 feet. Near Taylor's Falls it has been somewhat quarried for use as a building stone.

At Franconia, close below the Lower Dalles, it reaches in the bluff of Lawrence creek at Paul Munch's mill to a hight of about 70 feet above the creek or 90 feet above the St. Croix. Its upper 40 feet are a gray, thick-bedded sandstone, which is rather friable, but hardens after quarrying; it supplied the stone of which this mill was built, fifteen years ago. The next 12 feet are finely laminated, slightly sandy shale, soft, but hardening by exposure, green and iron-rusted, superficially ash-colored; and the 20 feet at the base are dark-greenish sandstone, soft and incoherent at the weathered surface.

The ravine of Lawrence creek for a half mile above this mill is inclosed by cliffs of this sandstone, mostly like the upper part of the foregoing section, rising 50 to 75 feet above the creek, and in their highest portion about 125 feet above the St. Croix river. Myriads of *Lingulæ,* difficult for preservation, excepting as fragments, because of the crumbling character of the stone, occur in these beds on each side of the creek, an eighth to a fourth of a mile north from the mill, at about the hight of the flume. The dip here is one to one and a half feet in a hundred, or about three-fourths of a degree, southward.

At Osceola, nearly opposite the southeast corner of Chisago county, the St. Croix sandstone is thinly capped by the Lower Magnesian limestone, which thence southward overlies this formation along the St. Croix and Mississippi rivers.*

Trenton limestone. The continuation of the St. Peter sandstone and Trenton limestone, which form St. Anthony's falls in Minneapolis, is shown by outcrops in the S. E. ¼ of section 34, Fridley, close east of the railroad. The limestone here is weathered to a buff color. Two exposures of it occur about a quarter of a mile apart, each having a thickness of about ten feet and lying between 40 and 50 feet above the river. Below the limestone at its more northern exposure, two or three feet of the underlying St. Peter sandstone are seen. These are the most northwestern outcrops of the Trenton and St. Peter formations in this state.

The railroad well at Anoka, twelve miles farther northwest, found the following strata in descending order, as reported by Mr. T. S. Nickerson, under whose superintendence it was bored: sand, 20 feet; reddish till, with water seeping from its upper portion, 60 feet; soft blue shale, 40 feet; harder shale, 20 feet; sand, about 2 feet; and hard rock, thought to be limestone similar to the Trenton limestone in Minneapolis and Saint Paul, 20 feet, in which the boring was stopped at a total depth of 162 feet. This is close to Anoka depot, 883 feet above the sea, and the stratum supposed to be the Trenton limestone is 740 to 720 feet above the sea. The overlying shales, according to this view, represent those found next above the Trenton limestone in East Minneapolis and in Ramsey county; but it seems perhaps equally probable that the part of this section below the till or glacial drift belongs wholly to the Cretaceous age, whose deposits, now mostly eroded or deeply buried by the drift, are known to have extended formerly over the western two-thirds of Minnesota.

Glacial and modified drift.

Glacial striæ, observed by Prof. Chamberlin at St. Croix Falls, bear S. 35° E., referred to the true meridian.

Red till overlain by blue till and yellow till. In the report of Wright county, a section at Dayton, opposite the southwest corner of Anoka county, is described and figured, showing reddish till overlain by dark bluish till, which

* See also the tenth annual report, pp. 116–120, where some particulars are stated bearing on the relations of the trap rock to the overlying strata of conglomerate and sandrock. [N. H. W.]

itself is overlain by yellowish till. Many sections of the drift in Anoka, Isanti and Chisago counties show that the diverse deposits of till noted at Dayton continue with the same stratigraphic order through a distance of seventy-five miles east-northeast from Wright county to the edge of Wisconsin. These distinctive colors, though presenting very notable contrasts with each other, might all be denominated gray, to which in the first a reddish tint is added, while the second is a darker and bluish gray, and the third lighter and yellowish. For convenience of designation, however, these divisions of the glacial drift are generally called simply red, blue, and yellow till.

The red till was brought by ice-currents which flowed southwestward from the region of lake Superior, and the blue till by similar ice-currents flowing from the region of lake Winnipeg and the Red river valley toward the south and southeast. This is known by their boulders and pebbles, which in the red till are fragments of the rock-formations about lake Superior, with none of limestone; but in the blue till they include many of limestone like that outcropping near Winnipeg, and occasional fragments of Cretaceous shale and lignite, and of petrified wood, such as are found in western Minnesota and in Dakota, while rocks peculiar to lake Superior are wholly wanting. The yellow till, extending from the surface to a depth that varies from 5 to 50 feet, but is most commonly between 10 and 30 feet, is merely the weathered upper part of the blue till, in which the small proportion of iron present has been changed, by exposure to air and percolating water, from protoxide combinations to the hydrous sesquioxide, or limonite. In the latter condition the iron gives something of the yellowish color of iron-rust to the till, as also to beds of modified drift and of recent alluvium. In the red till much of the iron remains as anhydrous sesquioxide, or hematite, in which condition it is the coloring matter of the red shales and sandstones of lake Superior. The gravel, sand and clay of modified drift associated in origin with the red till are similarly colored red. Weathering changes the iron from this condition more slowly than in the blue till and its associated modified drift. Its tendency is to produce in each the same light yellowish color, and this is occasionally seen on a surface of red till to the depth of one or two feet, but more commonly no change can be observed. Its influence on the red modified drift is usually limited to depths of only a few feet, extending lower in gravel and sand than in less pervious stratified clay and till.

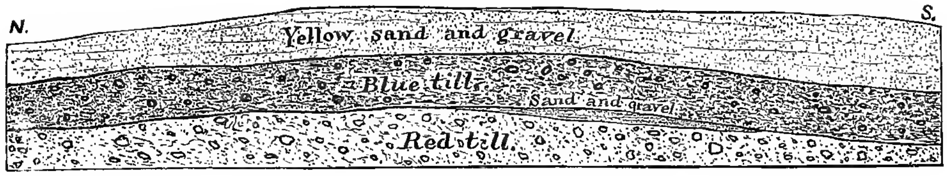


FIG. 29. RED TILL OVERLAIN BY BLUE TILL AT ST. FRANCIS BRIDGE.

Close south of the east end of the bridge in St. Francis, thirteen miles northeast from Dayton, the east bank of Rum river, undermined by a high flood shortly before this examination, showed a section 200 feet long and 35 feet high, as represented in fig. 29. Yellowish sand and fine gravel, horizontally stratified, reach from the surface to the depth of 10 to 15 feet; next below is dark bluish gray till, 10 to 12 feet thick, divided from the beds above and below by very definite lines, with no interstratification nor evidence of gradual transition or commingling, containing pebbles and stones up to one or two feet in diameter, in similar numbers as seen generally in the till throughout western Minnesota; and under this is reddish gray till, of which a thickness of 5 to 12 feet was seen in this section, reaching to the water-line, with many enclosed boulders and pebbles, somewhat more eroded by the river along certain horizontal lines than in other portions, but showing no other evidence of stratification. Both these deposits of till are thoroughly intermingled clay, sand, gravel and boulders, being typical boulder-clay or unmodified glacial drift. Neither contains, as seen in this section, any layer or lenticular bed or pocket-like mass of modified drift, such as are occasionally enclosed in till; but between the blue and the red till this section shows a layer of obliquely and irregularly bedded coarse sand and very fine gravel, 1 to 2 feet thick, extending about 50 feet, thinning out wedge-like at each end, beyond which the red till is overlain directly by the blue till. Many boulders up to two feet in diameter strew the shore of the river at the foot of this bank. Among these about one-fourth of all over three inches long are distinctly glaciated, and a sixth or an eighth of all show glacial striæ. They include fragments of dark and compact trappean rocks, frequent in the red till; gray and reddish granite, syenite and gneiss, found in both the red and the blue till; and limestone, found only in the blue till.* At the north end of this section, where the bank has not been

* Fragments of the Winnipeg limestone are found sometimes in the red till.—N. H. W.

recently eroded, at least to any considerable extent, this bed of blue till, long exposed to the effects of weathering, has assumed the light yellowish color that characterizes its upper part when it forms the surface.

At Franconia, thirty-two miles east from St. Francis, the bluff of the St. Croix river consists of yellow till to the depth of about 20 feet; then, stratified sand and gravel, about 50 feet; below which the red till appears, having a thickness of 50 to 75 feet or more, resting on the St. Croix sandstone. West from Franconia across the morainic belt that includes the Chisago lakes and reaches to Sunrise river, yellow till generally forms the surface, extending 15 or 20 feet in depth. At many places this is underlain, as in the bluff at Franconia, by thick deposits of modified drift; but sometimes these are wanting and red till immediately underlies the yellow till.

Northward the till in Chisago and Isanti counties is commonly yellow near the surface and blue at a considerable depth, and contains pebbles and large blocks or slabs of limestone. In sections 1 and 2, Spring Vale, and sections 5 and 6, Cambridge, numerous masses of limestone ten to twenty feet long are found, and many others of smaller size. One measuring fifteen feet in length and supplying twenty-one loads of stone was burned for lime by Andrew Bjorklund in the S. E. ¼ of section 6, Cambridge. The yellow and the blue till, enclosing limestone boulders, form the morainic belt of Maple Ridge, Stanchfield and Nessel, and continue several miles farther north into the edge of Kanabec and Pine counties. The underlying red till is sometimes reached by the channels of streams or by wells on this area. Because of the limestone ingredient of the upper deposits both of till and modified drift, the water of wells and springs throughout the three counties here reported is more or less hard, being unsuited for washing with soap.

The Ground House and Snake rivers in their course from west to east are approximately the northern boundary of this large district upon which the red till brought by ice from the northeast is covered by blue and yellow till from the west. Beyond these streams the surface of the country north and northeast to lake Superior, and as far westward as to Brainerd, Little Falls and Saint Cloud, consists of the red till, or of modified drift that is proved by the derivation of its pebbles and the absence of limestone, and often by its decidedly red hue, to have been likewise brought from the region of lake Superior. Wells and springs in this northeast part of the state supply soft water. Eastward the area on which the red till is overspread by blue and yellow till extends across the St. Croix river along the east side of Chisago county; and its southern boundary runs through the northwest part of Washington county and coincides nearly with the south line of Anoka county. The morainic hills in Fridley township are red till, and this, with red modified drift, forms the surface thence to Saint Paul and Stillwater.

The deposition of the blue till (weathered yellowish near the surface) upon the red till seems to have taken place during the later portion of the last glacial epoch. The cause of the changed course of the line at which the currents of the west and east portions of the ice-sheet met is to be found in the changed meteorological conditions of this time. During the increased ice-melting attendant upon the recession of the ice-fields, the prevailingly westerly winds sweeping over the western side of the ice-sheet upon the Coteau des Prairies and eastward became 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 the increased temperature enabled these winds to carry their moisture farther than when the ice had its greatest extent. Then the precipitation of rain and snow took place more upon the western side of the ice; but at this later time the precipitation, by reason of the causes here mentioned, probably became much greater than before upon the east part of the lobe of the ice-sheet that extended southeastward from the Red river valley. Before this, lake Minnetonka and central Wright county had been the limit where this ice-flow was stopped by the opposing ice-current from lake Superior; but finally, because of the relatively and perhaps absolutely greater thickness of this part of the ice flowing from the northwest, due as shown to climatic changes, its current pushed back that opposed to it on the east, covering the red till brought by that ice with blue till containing plentiful limestone boulders and other material from the west and northwest. The line where these ice-fields moving from the west and from the northeast met when the blue till was deposited over the red till, lies in the south part of Mille Lacs, Kanabec and Pine counties; and the western ice even flowed into the edge of Wisconsin, fully seventy-five miles east of the line where these ice-currents formerly met.*

Modified drift overlain by yellow till. The section of the drift forming the upper part of the bluff of the St. Croix river in Franconia, before described,

* The conclusions here stated were first published in an article on "Changes in the currents of the ice of the last glacial epoch in eastern Minnesota," *Proc. Amer. Assoc. for Adv. of Science*, 1883.

and the records of wells in this township and in Chisago Lake, Amador, Rushseba, Nessel, Cambridge and Isanti, given in a later part of this chapter, show that the blue or yellow till overlies quite extensive and thick deposits of modified drift. This is true of a large part of Chisago county from its southern to its northern boundary, thirty miles apart, and must be regarded as demonstrative proof that the ice which overspread this area from the northeast was wholly melted away, covering the land where it had lain with its modified drift, before the onflow of ice from the west brought the later blue and yellow till. How long this modified drift may have formed the surface cannot be known; but Mr. Robert Nessel's well, in the east part of Nessel township, containing wood and peaty matter in a layer of clay that is overlain by 8 or 10 feet of till, indicates that the time was sufficiently long, and the climate mild enough, to allow plants to take possession of the ground and attain a considerable growth.

The most remarkable area of modified drift overlain by till found during all my observations in this and other states is the plain, mostly very flat but in some parts slightly undulating, which extends from Mr. Nessel's five miles east by Rush City to the St. Croix valley. The surface of this tract is yellow till 10 to 20 feet deep, which lies on a greater but undetermined thickness of red sand and gravel. In this modified drift wells obtain water at depths that increase from 15 or 20 feet on the west to 25 feet at Rush City and 30 to 50 feet farther east, because on that side the water-bearing beds are cut by the St. Croix valley and drained into it by springs. The extent of this almost level tract of till in a direction parallel with the St. Croix river, forming the upland first west of its valley, with a hight 140 to 150 feet above the river, is about fifteen miles, from the south line of Rushseba north-northeast to the Snake river east of Chengwatana. For five miles of this distance, from section 35 north to section 2, Rushseba, it is known that thick beds of red modified drift are overlain by a continuous sheet of yellow till, 10 to 20 feet thick, which owes its singularly level contour to that of the earlier water-deposited sand and gravel on which it lies. Wells and sections cut by streams show that these formations reach five miles from west to east and have at least an equal extent from south to north, occupying the greater part of Rushseba township; and the continuation of the same plain of till northward to the Snake river makes it very probable that the underlying modified drift also continues through this whole distance. The retreat of the northeastern ice-fields had supplied a very large amount of modified drift, deposited from the floods formed by glacial melting, in their course through Chisago county to the Mississippi; this had become clothed with vegetation, including hardy species of trees, probably the tamarack and black and white spruce, the last of which grows to large size along the Mackenzie river nearly to the shore of the Arctic sea; when again this area was buried beneath a great depth of ice advancing slowly over it from the west.

Terminal moraines. The hills of red till in Fridley, the most southern township of Anoka county, and in Mound View, Ramsey county,* others continuing southward along the east side of the Mississippi river and a series of the same extending from Saint Paul north-northeast, seem to be included together in the third or Antelope moraine of the lake Superior ice-lobe, marking its boundary during a halt or re-advance after it had begun to retreat but previous to its great recession which was attended by the deposition of the modified drift overlain by yellow till in Chisago county. Following this, the farthest advance of the western ice-lobe, reaching into Wisconsin on the east side of Chisago county, and confluent with the northeastern ice in southern Mille Lacs, Kanabec and Pine counties, is believed to have been contemporaneous with the fourth or Kiester moraine. A slight withdrawal of the western ice had taken place when it heaped up the morainic accumulations in Maple Ridge, Stanchfield and Nessel on its northern margin and in Amador and Chisago Lake on the east. These are referred to the date of the fifth or Elysian moraine. Finally, the sixth or Waconia moraine is probably represented by the rolling and hilly till of St. Francis, Burns and Ramsey, in western Anoka county, and the prominent hills north of Elk River, formed by this western ice-lobe when it had retreated from all the district here described excepting its southwest border.

Modified drift deposited upon the latest till forms the surface of the greater part of this district, being stratified gravel and sand. Some portions of this formation, as in Grow and Oak Grove, Anoka county, much of Wyanett and Spring Vale, and about Long lake and Lower Stanchfield creek in the north part of Cambridge, are prominently rolling in swells and rounded hills 20 to 30 or even 50 feet high. These are more massive and have smoother slopes

* The Mound View hills consist of gray till. [N. H. W.]

than typical kames, but are doubtless of similar origin, owing their form to deposition by glacial streams in channels and basins melted out from the ice near its receding margin, while its unmelted portions remained on either side, occupying the places of the present depressions and hollows.

Nearly all of this modified drift, however, has the level or only slightly undulating contour which would be assumed by the deposits of streams and wide-spread floods discharged from the melting and retreating ice-fields and flowing over these areas on their course toward the sea. Taking into account the glacial movements upon this district, the time of deposition of this modified drift is found to have been during the retreat of the western ice-lobe from its moraine in northern Isanti county and in northern and eastern Chisago county, and during the early portion of its next retreat when it withdrew from the moraine in western Anoka county and north of Elk River. Great floods, with much modified drift, were poured down from the melting ice in these counties; and as soon as they were sufficiently uncovered, they became also the avenue of drainage for the water and modified drift set free by the glacial melting on areas reaching far to the west and north. From Stearns county the drainage was toward the east through Sherburne county and the south edge of Benton county, to Princeton, Spencer Brook and Cambridge, and thence south through Isanti and Anoka counties. From Pine county and from northwestern Wisconsin the drainage also converged toward this district, crossed the present course of the St. Croix river, and passed southwesterly through the central part of Chisago county, southeastern Isanti county, and across Anoka county to the Mississippi. A bluff eroded 40 to 60 feet below the general level along the west side of the floods from Wisconsin is a notable topographic feature about one and a half miles east of Harris, and extends thence six miles or more north-northeast, becoming merged in the east part of Rushseba with the bluff of the St. Croix valley. The series of lakes in Anoka and Isanti counties, before mentioned, may be also due to this drainage from the northeast.

Modes of deposition of the till and modified drift. The descriptions in the foregoing pages well illustrate the various ways in which the glacial drift and modified drift were deposited. At Dayton and St. Francis the red till, besides probably some part of the blue till, appears to be a ground-moraine deposited beneath the ice-sheet. This is indicated by the large proportion of planed and striated stones. It is also in accordance with what is known of the glacial movements on this district. If the line of confluence of the western and eastern ice was gradually transferred from central Wright county northeastward to Mille Lacs and Kanabec counties, it cannot be supposed that the red drift contained in the ice moving from the northeast at Dayton and St. Francis when these places were within the limits of that glacial current, was still retained in the ice there when the western ice-current extended over these localities and far beyond them to the north and northeast. Some portion of the red till there deposited below the blue till must doubtless be referred to this last glacial epoch, and seems to be necessarily a subglacial formation.

On the other hand, it is surely demonstrable that the modified drift and a large part of the till were held in the ice, mostly in its lower portion, so that during its final melting, when only a small thickness of the ice was left, its surface must have been covered by the drift which it had contained. A large part of this material fell in a comparatively loose, unstratified mass, forming the upper part of the till, and covering the land upon which the ice had lain, whether this was bed-rock, a ground-moraine, or till formed in an earlier glacial epoch. Other parts of the drift contained in the ice and finally exposed on its surface were washed away by its streams and deposited as modified drift, forming beds of gravel, sand, and fine silt, along the course in which the floods supplied by the glacial melting flowed toward the ocean. The great deposits of stratified sand and gravel both beneath and above the latest till in this district are satisfactorily referred to this origin. Not all of the modified drift, however, was deposited in this way, for many layers and veins of sand and gravel that are contained in the till, often yielding copious supplies of water in wells, were undoubtedly made by small subglacial streams.

The till covering the earlier modified drift and forming the plain at Rush City appears not to have been deposited until the ice in which it had been held was melted away. This ice in its onflow did not erode the modified drift, at least in any considerable amount, else its level contour would be destroyed; and at the same time it seems impossible that a sheet of till having so uniform thickness upon so large an area could be formed as a ground-moraine. Obviously the till here was brought to this area and spread upon it while it was contained in the mass of the onflowing ice, and it seems almost equally sure that it remained thus in the ice till this was melted. More detailed and critical observation and study of the drift throughout this region is very desirable, and would doubtless add much to our knowledge of the conditions of the glacial period and the modes of deposition of the drift.

Terraces. The valley in which the St. Croix river flows was partly eroded after the deposition of the latest till and the overlying modified drift. Probably this river had the same course, however, before the ice age and in the interglacial time preceding the advance of the ice from the west. Terraces of sand and coarse gravel were noted on the southwest side of this valley, at hights approximately 90 and 125 feet above the river, in section 2, Shafer, about five miles north of Taylor's Falls. These terraces measure an eighth of a mile or more in width; and the upper one is at least three-fourths of a mile long. On the Wisconsin side opposite these and for two miles farther north, a similar terrace is seen about 90 feet above the river. A few miles farther northwest, in the northeast part of Amador, a terrace like the foregoing, 75 to 90 feet high, extends three miles with a width varying from a half mile to one and a half miles. This is limited on the east by the river, and on the west by morainic hills 75 to 100 feet higher. Most of its surface is nearly level, but some portions are undulating, with swells 10 to 25 feet above the depressions. It is a continuation from the "jack pine barrens" of such sand and gravel in northwestern Wisconsin, which occupy a considerable width on the east side of the St. Croix, and extend thence in a broad belt a hundred miles northeastward. The drainage from the melting ice-fields on the northeast seems thus to have been divided, a part of the floods being carried southwest across Chisago and Anoka counties, and a part going southeast and south in the St. Croix valley, filling it in Amador and Shafer with modified drift to a depth of about 90 feet above the present river.

Alluvium. Only narrow and interrupted alluvial bottomlands of recent formation are found on the St. Croix and Mississippi rivers in these counties.

Dunes of sand, gathered from the modified drift by the wind, and heaped up in mounds and ridges 10 to 20 feet high, occur in the south part of sections 34, 35 and 36, Grow, Anoka county. They are blown into frequently shifting forms, like drifts of snow, and are too unstable to give a foot-hold to vegetation. It seems most probable that they were gathered from the coarser sand and gravel of the surrounding area soon after the deposition of those beds, before they became covered, and protected from wind erosion, by grass, bushes and trees.

Ice-formed ridges. Very interesting ridges of sand and gravel have been formed in the north part of Green lake, five miles east from Wyoming in Chisago county. They have been pushed up from the lake-bed by ice, aided by the fluctuations in the level of the water, which is in different years sometimes much lower and much higher than its average stage. Two of these ridges, starting from the east shore, extend into the lake about a third of a mile, or nearly to its west shore, converging so as to meet like the sides of the letter V, and enclosing a triangular portion of the lake between them. They are five to ten rods wide, and vary from three to eight feet in hight. On the southern one a road is built, crossing the lake. Similar ridges occur on the shores of many other lakes in this district, most frequently where they are bordered by marshes or by land only slightly higher than the water-level.

Wells in Chisago county.

Nessel. Robert Nessel; sec. 19, the east edge of the township: well, 15 feet deep; soil, 2; yellow till, 8; soft blue clay, with peaty portions and decaying fragments of wood, offensive in smell, 4 feet; and sand, dug into 1 foot, from which water rose quickly six or eight feet. Other wells in this neighborhood vary from 12 to 22 feet in depth, and are similar to this.

Stephen Clark; sec. 30, in the southeast part of the township: well, 22 feet; all very hard till, yellowish above, but bluish in its last 6 or 8 feet.

Andrew Erickson; sec. 31, in the southwest corner of the township: well, 22 feet; soil, 2; yellow till, 16; sand, with water, 4 feet and continuing deeper.

Matts Collin; sec. 32, a quarter of a mile northeast from the last: well, 42 feet; soil, 2; till, 35; and sand, with water, 5 feet and continuing deeper. This vicinity has a morainic contour, in hillocks and swells 10 to 30 feet high.

John Lelman; sec. 35; well, 35 feet; soil, 2; till, 30; and a bed of sand and gravel dug into 3 feet, with water rising above it a few feet.

Rushseba. The wells at Rush City are all about 25 feet deep, being soil, 2 feet; hard yellow till, requiring to be picked, 10 feet; and red gravel and sand below, in which water is found 20 to 25 feet from the surface.

Archibald Peers; sec. 14, one and a half miles east-northeast from Rush City: well, 32 feet; soil, 2; yellow till, picked, 16; and red sand, 14, extending deeper, with water in its lower part.

Daniel McCloud; sec. 22, a half mile southeast from Rush City: well, 22 feet; soil 2, very hard yellow till, picked, 12; and sand, 8, extending deeper, with water.

John Flynn; sec. 23: well, 40 feet; soil, 2; yellow till, 14; and sand, 24, water seven feet deep. Another well, fifteen rods southwest from this, 36 feet deep, was sand for its lower 18 feet.

Henry Overman; sec. 35: well, 48 feet; soil, 2; yellow till, 6; and red sand, 40, with only a scanty supply of water. The valley of a creek a few rods farther north shows a similar section; as also another valley crossed by the road about five miles farther north, near the south line of sec. 2.

Fish Lake. J. S. Sayer; at Harris station: well, 60 feet; soil, 2; sand and gravel, 15; and blue till, 43 feet; water rose fifteen feet from gravel at the bottom.

G. W. Flanders; also at Harris: well 22 feet; soil, 2; reddish sand, with streaks of blue clay up to two inches thick, 16 feet; and dark, very hard till, 4 feet and extending lower; water is found at the top of the till.

Frederick Hals; Stark post-office, sec. 26: well, 19 feet; yellow till, hard, picked, 3 feet; harder reddish till, 16 feet; water rose three feet from quicksand at the bottom.

Sunrise. A. D. Sayer; sec. 22, T. 36, R. 21, on the west side of "Goose creek meadow," at the base of a bluff 50 feet high, which rises to the general level of the county westward: well, 21 feet; soil, 2; stratified sand and clay, 4; red till, requiring to be picked, 10 feet; much harder red till, 5 feet, and continuing deeper, from which water seeps.

Branch. A. F. Swanson's steam flouring mill, in the north part of the village at North Branch station: well, 28 feet; soil, 1; sand, 12; yellowish till, 14; and red sand below, dug into 1 foot, from which water rose eleven feet. Within twenty rods farther south wells of the same depth are all gravel and sand, in which water is obtained before reaching the till. In the banks of the North branch of Sunrise river, close north of this village, the till rises nearly to the surface, having only five feet or less of overlying sand.

Amador. Charles Martin; sec. 6: well, 8 feet; soil and gravel and sand, 7 feet; underlain by red till, dug into 1 foot; a scanty supply of water comes at the junction of the modified drift and till. Within a mile farther south, in sec. 8, wells on this terrace of modified drift are 50 to 75 feet deep, all the way in gravel and sand.

C. C. Cowan; sec. 12, on the morainic belt two miles west from the preceding: well, 111 feet; soil, 2; till, 16; and gravel and sand, 93; no water.

Wyoming. Wells at Wyoming station are 10 to 20 feet deep, all sand and fine gravel, with plenty of water.

John D. Koch; sec. 30: well, 22; soil, 2; all sand below, with water in quicksand at the bottom.

Chisago Lake. P. I. Johnson; Center City hotel: well, 70 feet; soil, 2; sandy yellow till, 15; and sand 53 feet, to water found 35 feet below the level of Chisago lake, not rising. John A. Hallberg, at the Lakeside hotel in Center City, has a well 65 feet deep, similar to the last. The till that forms the surface of this region, making nearly impervious lake-basins, is underlain by a great thickness of modified drift, in which the plane of saturation lies much lower than the lakes.

Franconia. Olaf Slatengreen; sec. 14, nine miles southwest from Taylor's Falls: well, 80 feet; soil, 2; sand, 3; till, yellowish in its upper part, and red below, 74 feet; and sand, 1 foot, to bed-rock; no water. John A. Carlson's well in the same section, 104 feet deep, was mostly till and found many boulders of fifty to a hundred pounds' weight in its last four feet; it has about four feet of water.

Wells one to two miles west of Franconia village, on the upland 200 feet above this village and the St. Croix river, go through 20 or 30 feet of yellow till, below which they encounter an equal thickness of caving gravel and sand.

Wells in Isanti county.

North Branch. Jacob Dall; sec. 14: well, 30 feet; soil, 2; hard yellowish till, picked, 28; water rose five feet from sand at the bottom.

Stanchfield. Walter J. Downs; sec. 18: well, 20 feet; soil, 2; yellowish till, very hard, requiring to be picked, 10; and blue till, 8, from which a good supply of water seeps.

Andrew Wilson; sec. 35: well, 27 feet; soil, 2 feet; yellow till and blue till below, both picked, 25 feet; water rose from the bottom five feet in as many minutes.

Cambridge. H. Miden; sec. 6: well, 14 feet; soil, 2; yellow till, 5; and sand, 7, extending also lower, containing plenty of water.

In Cambridge village wells are 20 to 35 feet deep, all in sand, obtaining an ample supply of excellent water.

Olaf Bergman; sec. 29: well, 46 feet; soil, 2; sand, 29; gravel, 2; and blue clay, probaby till, 13; water rose six feet in a few minutes.

Isanti. In Isanti village the wells are nearly as at Cambridge, being 15 to 25 feet deep, all sand and gravel, to water.

Mrs. K. Check; sec. 24: well, 37 feet; soil, 2; yellowish till, hard, requiring to be picked, 20; and dark bluish till, 15 feet, also continuing lower; the only water obtained seeps at the junction of the yellow and the blue till.

John Linberg; sec. 24, a quarter of a mile northwest from the last: well, 48 feet; soil, 2; yellow till, 20; blue till, quite hard, yet softer than the yellow, 14; and sand, 12 feet and continuing lower, dry in its upper part, but containing water at the bottom. A piece of lignite four inches long was found in the till twenty-five feet below the surface.

Andrew Norin; also in sec. 24: well, 40 feet; soil, 2; yellowish till, picked, 36; sand, 2; and coarse iron-rusted gravel at the bottom, from which water rose ten feet in a few hours.

Athens. George D. Bennett; sec. 22, in the southwest corner of the township: well, 20 feet; soil, 1 foot; sand and gravel, 14; and dark bluish till, picked, 5; water, found in a gravelly layer at the bottom, rose four feet.

Spencer Brook. E. G. Clough; in the village, N. W. ¼ of sec. 15: well, 18 feet; soil, 2 feet; all below is sand and gravel, becoming coarse near the bottom; water plentiful and excellent. Wells throughout this township are 15 to 30 feet deep, wholly in sand and gravel.

Wells in Anoka county.

Centerville. William J. Ramsden; N. E. ¼ of sec. 4: well, 40 feet, all sand; water in abundance was found at 18 feet, but filled the pipe with quicksand, to avoid which the well was bored deeper.

Oliver Parenteau; sec. 14: well, 11 feet; soil, 2; hard, yellow till, 9; water rose four feet from a layer of sand one foot thick at the bottom.

Basil Landroches; in the village, sec. 23: well, 17 feet; soil and sandy loam, 6; and hard yellow till, 11; water comes from a vein of sand at 15 feet.

Blaine. J. W. Winder; S. W. ¼ of sec. 32: well, 40 feet, the deepest in this vicinity; all sand to water at the bottom; no gravel so large as a half inch in diameter.

Fridley. Thomas Casay; N. W. ¼ of sec. 3: well 90 feet, dug 45, bored 40, and driven the last 5 feet; soil, 1; sand, 15; blue till, containing stones up to eight inches in diameter, 17; and sand, mostly quicksand, with occasional clayey layers, but no gravel, 57; at 90 feet a hard layer was struck, perhaps the bed-rock.

Oak Grove. N. A. Nason; sec. 19: well, 37 feet; soil, 1; gravel and sand, 29; and till, picked, 7; water came at the top of the till.

Grow. Capt. Nathanael Small; S. E. ¼ of sec. 5: well, 30 feet; soil, 2; sand, 10; gravel, 8; interbedded gravel and sand, with occasional thin clayey layers, 10; good water in large supply from quicksand at the bottom.

Anoka. Bean & Guderian; in the city: well, 40 feet; gravel and sand, 20; and reddish till, 20; water rose suddenly from gravel at the bottom, attaining a depth of about twenty feet. While this well was filling up, another about a dozen rods away was drained; but within an hour this well regained its usual amount of water.

The railroad well in Anoka, reaching the bed-rock at 80 feet, has been described in a former part of this chapter.

St. Francis. Wells at St. Francis village are 20 to 30 feet deep, going through 10 to 20 feet of sand and gravel, with till below. A third to a half mile west from the river wells are wholly in modified drift.

The following are in the west half of this township (range 25):

Stephen Francis; sec. 25: well, 26 feet; soil, 2, yellow till, picked, 24; water seeps.

Lemuel Bull; sec. 27: well, 35 feet; all till, yellowish above and dark bluish below; water rose quickly four or five feet from a sandy vein at the bottom.

John Axelson; sec. 30: well, 40 feet; soil, 1; sand, 10; till, 5; modified drift, sand and gravel, witb thin clayey layers, 24; water at bottom, not rising.

Burns. Andrew Mattson; N. W. ¼ of sec. 2: well, 18 feet; soil and gravel, 3 feet; yellow till, picked, 8; darker reddish till, somewhat harder, 7; water two feet deep seeps from a vein of quicksand.

John D. Keen; sec. 30: well, 44 feet; soil, 1; yellow till, spaded, 10; sand and gravel, 6; harder red till, 27; water seeps at the bottom, becoming two or three feet deep.

Ramsey. Austin Chamberlain; sec. 8: well, 16 feet; all gravel and sand; large supply of good water.

James Collins; sec. 19: well, 37 feet; soil, 2; yellow till, 15; blue till, 18; and sand, 2, with water rising from it three feet.

MATERIAL RESOURCES.

The chief industry and source of wealth in this district is agriculture. Much of the original growth of wood has been cleared away for farms, and this is still going forward; but enough will probably always remain for ample supplies of fuel. The species of maple, ash and oak are also valuable for manufacturing and building purposes.

Mining for copper and silver has been attempted at Taylor's Falls, but without encouraging results, though the trappean rocks of that vicinity belong to the same formation which contains the rich copper mines of upper Michigan. Masses of native copper, transported in the drift from this formation in the region of lake Superior, are found rarely, but afford no indication of the occurrence of this metal in adjacent rock-outcrops. A mass of such drift copper weighing seventy pounds, found near Taylor's Falls, is in the museum of the Minnesota Academy of Natural Sciences. Another weighing fifteen pounds was found in the drift at Sunrise, close above the upper bridge.

Water-powers utilized in these counties, mostly for flouring mills, are as follows:

On the St. Croix river at St. Croix Falls, twelve feet head; the dam was carried away several years ago, and has not been rebuilt.

A mill on Goose creek west of Harris has been discontinued because the dam overflowed valuable hay-meadows.

On Rush creek the Rush City mill, owned by Spivak & Martin, manufacturing both flour and lumber, in section 14, Rushseba, has a head of fourteen feet. Another good water-power, affording a head of ten feet or more, exists on this creek where it crosses a ledge of the St. Croix sandstone about half a mile above its mouth.

On Sunrise river are the Sunrise City mill, owned by Franklin Low, twelve feet head, flowing back nearly two miles; and the Riverside mill, belonging to the John G. Mold estate, in Sunrise below the foregoing, also twelve feet head. A water-power of ten feet head, not yet used, is reported on this river about four miles southwest from Sunrise, on Mr. Farr's farm.

The Franconia mill, owned by Joseph Groll, on Lawrence creek, has a head of thirty feet, using an overshot wheel; flume a quarter of a mile long, with a descent of two feet; dam ten feet high; stream mainly formed by very large springs within a quarter of a mile above the dam; flow nearly constant throughout the year, affording seven horse-power. Steam power has been added.

No water-power is used on the Rum river in Isanti county. The following powers are on its small tributaries in this county:

Spencer Brook mill, owned by S. S. Griggs, leasing to J. H. Foster; at Spencer Brook village; head, nine feet.

A mill owned by Eklund & Ossell, on the Upper Stanchfield creek, in the northwest corner of section, 11, Spring Vale; head, six feet.

Stanchfield mill, owned by Peter Trolin & Co., on the Lower Stanchfield creek, in section 34, Stanchfield; head, eight feet.

Oliver Larson's mill, in section 9, Isanti; head, four feet.

The mill formerly owned by Peter Hadean, in section 19, Isanti, on the same brook as the last, has six feet head.

Anoka county had the following water-power mills:

St. Francis mill, owned by D. Woodbury & Son, manufacturing both flour and lumber on the Rum river at St. Francis; head, nine feet.

Lincoln mill, owned by W. D. Washburn & Co., on the Rum river at Anoka; capacity six hundred barrels of flour per day; head, ten feet; burned in 1884 by the fire which destroyed a large portion of this city.

Keystone mill, on Rice creek at Fridley; head, 15-16 feet, one Victor wheel of 17½ inches; thirty horse-power, owned by S. H. Baker and Co.

Building stone. Some portions of the St. Croix sandstone have been quarried for building purposes at Taylor's Falls, being used in one or two business blocks. Goll's mill in Franconia is also built of this stone. It is of rather coarse grain and friable on first quarrying, but the weather operates to harden it in a few months. The Trenton limestone in section 34, Fridley, has also been slightly quarried. Throughout these counties the boulders of the drift are commonly used for coarse masonry, as cellar-walls and well-curbing.

Lime. Travertine, a limestone deposited from the water of springs, occurs in large deposits on the face of the bluffs of the St. Croix sandstone, and has been extensively burned for lime, a quarter to a half of a mile south of Goll's mill in Franconia, and near Osceola, a few miles farther south on the Wisconsin side.

Boulders of magnesian limestone from the drift have also been burned for lime at numerous places, as in Cambridge, Spring Vale and Stanchfield by Andrew Bjorklund, Peter Franzen and P. D. Linberg; in Wyanett by Charles Brattlund; and in Burns by George J. Wheeler, Christopher Celhaver, George Melkson and Clarence White. The annual product of lime from boulders, however, does not exceed a thousand barrels. It is sold at about $1 per barrel. In Burns township about a third part of the limestone boulders, usually distinguished by a more reddish color, yields dark lime which makes a yellowish wash or plaster; while the other two-thirds yield white lime.

The quarries in the Trenton limestone on the Hennepin-Anoka county line are owned by H. T. Welles and Wilcox & Hempel.

Bricks. The most considerable business in brick-making in these counties is in the south part of section 34, Fridley, about two miles north of Minneapolis. At the date of these notes (1880) work was being done here by C. J. Swanson & Co, and by Peterson & Benson, each having begun in 1879. The clay used is modified drift forming the east bank of the Mississippi river. The section is gravel and sand at the top, 5 to 12 feet; clay, partly dark and partly weathered to a yellowish color, levelly stratified, 8 feet; and dark clay, mostly in level layers, but in some portions irregularly laminated and contorted, 25 feet, reaching ten feet below the level of the river; with quicksand beneath. The bricks are cream-colored, and require no sand for tempering. Mr. Swanson's product in 1879 was 1,800,000, and Peterson & Benson's was 1,500,000, sold at $7 to $8 per thousand.*

On the west side of Round lake in Grow township, two miles northeast of Anoka, brick-making was begun by Kelsey Brothers in 1871. Their product in 1879 was 600,000, worth $6.75 per thousand at the kiln, or $8 loaded on the cars at Anoka. The clay is 10 to 14 feet thick, gray, partly weathered to yellowish, levelly stratified, and is underlain by bluish quicksand. Its top is 8 or 10 feet above the lake, or about 35 feet above Rum river. The bricks, as in Fridley, are cream-colored, and need no intermixture of sand. Curved bricks for well-curbing are also made by the Kelsey Brothers and are sold for $8 per thousand. Another yard is owned by — Nebulon.

There is a great industry in red pressed brick at Coon creek. There is said to be a very large amount of suitable red clay. The two parties operating red-pressed brick yards in 1885 were—*The Anoka pressed brick and Terra Cotta Company*, and C. Benson. The clay needs about the same in bulk of sand added to make it right for this manufacture.

Several kilns of cream-colored bricks of good quality were burned in 1879 in the east part of Stanford by P. O. Widmark.

* In 1885 Nels. Peterson made three and a half millions of brick, delivering them in Minneapolis at $7.50 per thousand, and C. J. Swanson made four millions. John Bowers, just south of the county line, in Hennepin county, sold about one million. Mixed wood costs, delivered at the yards, from three to three and a half dollars per cord. This clay is the same as that used at Shingle creek, on the west bank of the Mississippi river. The beds are singularly stratified. The entire mass of clay undulates up and down sometimes forming angles of 10° to 20° with its own directions at different places. Besides this general undulation there is a most singular contorted, or concentric, or convoluted, finer lamination in some of the individual layers. This is brought out, on the weathered face of the excavated bank. The clay is essentially the same from top to bottom, 18–20 feet, and this curious internal structure seems to have been caused by eddying motions in the water which came on periodically. These contorded beds are from three to eighteen inches thick. This clay extends much further north and northeast, probably lying under an extensive marsh half a mile at least. [N. H. W.]

A kiln of 10,000 red bricks of good quality was burned in 1881 on the east side of Rum river a half mile southwest from Cambridge, by Nordfeldt, Peterson & Co. Two parts of sand were mixed with three of clay for tempering.

In Wyanett red bricks are made on the northwest side of Green lake by Eric Brattlund.

In section 14, North Branch, red bricks are made by Frank Ekstrom, using till or boulder-clay, with which sand is mixed in the proportion of one to three. His product is about 30,000 yearly, selling at $9 per thousand. Some of these bricks are damaged or spoiled by cracking after they are burned, on account of the slacking of the particles of lime in them due to the limestone gravel in the till.

Red bricks were also made during several years from the till on the south side of Rush creek at Rush City, by Archibald Peers. Only about a third part of these could be used, the remainder being crumbled by lime particles. In 1880 brick-making was again begun at a point close east of the railroad one and a half miles south of Rush City, by M. T. Spooner.

In section 16, Nessel, on the west side of Rush lake, red bricks of fair quality were made from till in 1879 and 1880 by John Anderson.

In 1856 red bricks were made near Low's mill in Sunrise. They are said to have been of good quality, with no lime particles nor gravel; no sand was used for tempering.

A mile southwest from Franconia, and again a mile northwest from Taylor's Falls, red bricks have been made from the till, but unsuccessfully because of lime particles.

The Catholic church at Centerville is made of brick clay burned at Centerville.

Peat of good quality exists in many of the marshes and swamps of this district. It has been prepared for fuel in considerable amounts by Mr. Dwight Mitchell near Coon Creek station in Anoka.

ABORIGINAL EARTHWORKS.

Chisago county. In Chisago Lake township five artificial mounds of the usual dome-like form, three to five feet high, were found in the woods at the northeast side of the north end of Green lake. They lie in a series some twenty-five rods in length, being six to ten rods from the lake and on land about 20 feet above it. A sixth of a mile farther northeast is another mound, in the woods beside Chisago lake. It has been partly excavated, having now a hight of eight feet, but originally it was probably twelve feet high. It is on land about 12 feet above Chisago lake and six rods from the shore. This mound is made of dark earth, and contains occasional fragments of stone up to a foot in diameter.

Three miles farther northeast, a mound seven feet high is on the island which the railroad and highway cross close southwest of Center City; and another of similar hight occurs an eighth of a mile southwest from this, on the west shore of Chisago lake just south of these roads.

In Fish Lake township a mound four feet high is situated close north of the road near the middle of the north side of Fish lake, on land of Eric Berglund; and another, originally ten feet high, is on the east side of Goose lake about a quarter of a mile south from its outlet, on land of N. P. Swanson and near his house.

A mound ten feet high is reported on the Kingsbury farm, on the southwest side of Rush lake, probably in section 23, Nessel.

Isanti county. On the west side of Lower Stanchfield creek and lake, in section 5, Cambridge, is a mound about fifteen feet high, which has been dug into, finding bones.

Another about fifteen feet high lies close to the west side of a lake through which Spencer brook flows in section 19 of Spencer Brook township. From this several skeletons have been exhumed.

In section 4 of the east part of Stanford a mound ten feet high is situated in Dr. Delvendahl's garden. This is on the southeast side of lake Henrietta.

Anoka county. At Michael Dupre's house, in the south part of section 15, Centerville, west of the outlet of Peltier lake and close north of Centerville lake, is a mound thirteen feet high. Mr. Dupre has partially excavated it for a hennery, finding several skulls. The bodies were buried with the heads toward the east. No implements were found. Within an eighth of a mile westward from this are nine low mounds, not so definite at the edge as usual, probably from having been plowed over, each being three or four feet high and about fifty feet across.

In Linwood aboriginal mounds are found on the north side of Island lake, and on the southwest side of Linwood lake. One in the latter locality was opened by Mr. Philip S. Harris of Saint Paul, finding bones.

Three other mounds, each about ten feet high, were learned of in Anoka county, as follows: one in the N. W. $\frac{1}{4}$ of section 36, two and a half miles west of St. Francis; another on the southwest side of lake George in Oak Grove, partly excavated, finding bones; and a third on land of the Kelsey Brothers at the west side of Round lake in Grow township.

It is noteworthy that nearly all the mounds in these counties are close to the shores of lakes.

CHAPTER XV.

THE GEOLOGY OF BENTON AND SHERBURNE COUNTIES.

BY WARREN UPHAM.

Situation and area. Benton and Sherburne counties (plate 46) lie in the east part of central Minnesota. The Mississippi river is their southwestern boundary. Elk River, the county seat and largest town of Sherburne county, is about twenty-five miles northwest from Minneapolis and thirty-five miles from Saint Paul. Sauk Rapids, the county seat and largest town of Benton county, is thirty-five miles northwest from Elk River. Big Lake, Becker and Clear Lake in Sherburne county on the Saint Paul, Minneapolis & Manitoba railway, and Rice's station in Benton county on the railroad from Saint Cloud and Sauk Rapids to Brainerd, are important villages.

Benton county has a length of twenty-eight miles, measured from east to west on its northern boundary; its width is twenty-four miles; and its area is 406.36 square miles, or 260,074.31 acres, of which 2,275.41 acres are covered by water.

Sherburne county is thirty-one miles long from east to west; its extreme width, measured on its eastern boundary, is twenty-one and a half miles; and its area is 468.88 square miles, or 300,086.12 acres, of which 12,905.72 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The chief affluents received by the Mississippi river in these counties are the Platte river, which in its last three miles crosses the west end of Langola township; the little Rock creek, draining the greater part of Langola and northwestern Watab, and flowing through Little Rock lake; and the Elk river, having its farthest sources on the northern boundary of

PIONEER PRESS CO. LITHO. ST PAUL

Benton county, flowing first about twenty-five miles south-southwest and south across this county, and then nearly thirty miles southeasterly through Sherburne county in a course approximately parallel with the Mississippi river and only three to five miles distant from it. The most considerable tributaries of the Elk river are Mayhew creek from the west in Benton county, and Stony or Rice creek, St. Francis river and Tibbetts brook from the east in Sherburne county.

Rum river, tributary to the Mississippi farther southeast, flows through the northeast corner of Sherburne county, and its West branch drains the northeast edge of Benton county.

Lakes. Benton county has comparatively few lakes, the most noteworthy being Little Rock lake, three miles long from north to south, in Langola and Watab; Mayhew lake, about three-fourths of a mile long, on the creek of this name in the east part of Watab; and Minden lake, about a mile long in sections 27 and 34, Minden.

Frequent lakes, up to a mile or a mile and a half in length, occur in Sherburne county, including Clear lake and Big lake; which give their names to townships; two Elk lakes, through one of which the Elk river flows on the south line of Palmer, while Battle creek, a tributary of St. Francis river, flows through the other; Briggs lake, close north of the first Elk lake; St Francis lake, on the St. Francis river in the south part of Blue Hill township; lake Fremont in the north part of Livonia, the source of Tibbetts brook; and Eagle lake in the southwest corner of Orrock.

Topography. The surface of Benton county is chiefly till, which rises with smooth long slopes to hights 20 to 30 or sometimes 40 to 60 feet above the streams. Occasionally this deposit presents a more irregularly broken contour, but it forms no prominent hills. Nearly level tracts of gravel and sand belonging to the modified drift, 40 or 50 feet above the Mississippi, Elk and St. Francis rivers, occupy the western two-thirds of Langola, the northwest part of Watab, and the south edge of Minden, St. George and Glendorado.

About five-sixths of Sherburne county is modified drift, or stratified gravel and sand, mostly spread with a flat or only slightly undulating surface, but interspersed here and there with lakes, which lie 15 to 25 feet below the general level. The banks bordering the lakes are often steep, rising within a few rods to the hight of the surrounding country. Adding the depth of the lakes, which ordinarily ranges from 10 to 30 feet, the entire depth of these basins is 25 to 50 feet. The streams crossing this plain of modified drift have eroded channels or valleys 25 to 40 feet deep, and the Mississippi river is only 40 to 50 feet lower than the part of this area which separates it from Elk river.

A rolling and hilly belt of morainic till about a mile wide and 25 to 50 feet higher than the adjoining country reaches from section 7, Haven, east to section 9, Palmer. Till also forms the hill known as Blue mound, about 75 feet high, in the N. W. ¼ of section 28 of Blue Hill township, so named from this mound. It is about a quarter of a mile long from northeast to southwest, with two-thirds as great width; its steepest slopes are on the north and northeast. Morainic hills of till, covered to a considerable extent by modified drift, 50 to 100 feet above the general level, occupy a nearly circular area about four miles in diameter, from a half mile to four and a half miles north of Becker station. The greater part of this area is on the northeast side of Elk river, but it includes also a tract some two miles long and one mile wide southwest of this river.

Hillocks and ridges 10 to 30 feet and in part 50 feet high, composed of sand and gravel of kame-like origin, form a narrow series extending east-southeasterly across Craig prairie in sections 16, 17 and 21, Orrock; and others of the same kind are found in sections 25 and 36, and also west of Eagle lake in section 31, of this township. A few miles farther southeast, much of the north half of Elk River, with section 34, Livonia, consists of kame-like hills and ridges of modified drift, trending from north to south and ranging from 40 to 100 feet in hight. They are most prominent on the west side of the Elk River and Princeton road. In some spots these hills are plentifully strown with boulders, but their material is mostly stratified gravel and sand.

Southward, in the central and southeast portions of Elk River township, this tract changes to one still more prominently hilly, with a typical morainic contour, the elevations being 50 to 200 feet above the intervening hollows. Their greatest hight, west of the Princeton road about two miles north of Elk River, is approximately 300 feet above the Mississippi river, or 1,150 feet above the sea. Here and for several miles thence to the west and to the southeast, reaching in all some eight miles, from near the mouth of Tibbetts brook to the N. E. ¼ of section 12, three miles southeast of Elk River, the material of the hills is mostly till with many boulders, and their trend is in the course of this belt, or from west to east and southeast.

Morainic till in low hills and ridges 20 to 40 feet high, with no prevailing parallelism in their trends, occupies sections 25 and 36, Livonia, extending thence east into St. Francis and Burns in Anoka county. The only smooth, slightly undulating till in Sherburne county is a few miles northwest from the last, being the heavily wooded tract in the central portion of Livonia, two miles in extent from north to south, crossed by Tibbetts brook and by the Princeton road.

Elevations, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

Fergus Falls line.

	Miles from Saint Paul.	Feet above the sea.
Elk River	38.8	896
Elk river, water, 896; grade	43.3	910
Bailey	43.9	921
Big Lake	47.9	940
Becker	55.8	977
Clear Lake	62.9	997
East Saint Cloud	73.5	1027
Mississippi river bridge, grade	74.1	1033

Saint Cloud & Hinckley branch.

	Miles from Saint Cloud.	Feet above the sea.
Saint Cloud	0	1038
Elk river, water, 1016; grade	7.2	1045
Rice creek near Foley's mill, water, 1120; grade	14.5	1132
Creek near St. Francis siding, water, 1108; grade	17.0	1113
St. Francis river, water, 1105; grade	17.7	1112

Elevations, Saint Paul and Northern Pacific railroad.

From C. A. F. Morris, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Sauk Rapids	76	1009
Mississippi river at the mouth of Sauk river	76	988
Watab	82	1053
Little Rock creek, water, 1007; grade	85	1020
Rice's station	89	1059
Platte river, water, 1059; grade	95	1069

The following elevations of the Mississippi river at its ordinary low-water stage along the southwestern boundary of these counties have been determined by the United States engineer corps under the direction of Capt. C. J. Allen. (These figures require a subtraction of three or four feet to accord with the railroad elevations preceding.)

Mississippi river.

	Feet above the sea.
At the mouth of Platte river	1029
(Platte river at the highway bridge	1038)
At the mouth of Little Rock creek	1006
(Little Rock creek at the highway bridge	1009)
At Watab	1004
At the mouth of Sauk river	992
At the railroad bridge, Saint Cloud	969
At Bridgeman's steam saw mill, Saint Cloud	964
At Saint Augusta and foot of the "Thousand islands"	949
At Clearwater	938
At the head of Bear island, near the west line of Becker township	924
At Monticello	893
At Elk River	853
At Dayton and the east line of Sherburne county	843

The highest land in Benton county, in the north part of Alberta, is about 1,150 feet above the sea, or some 200 feet higher than the shore of the Mississippi river at East Saint Cloud, which is its lowest land. Estimates of the average hights of its townships are as follows: Alberta, 1,140 feet; Maywood, 1,120; Glendorado, 1,075; Gilmanton, 1,100; St. George, 1,060; Langola, 1,080; Watab, 1,070; Minden, 1,050; and Sauk Rapids, 1,040. The mean elevation of Benton county, derived from these figures, is 1,090 feet.

The highest hills in Elk River and the shore of the Mississippi in this township are respectively the highest and the lowest land in Sherburne county, their difference in elevation being about 300 feet. The average hights of the townships are estimated as follows: Baldwin, 1,025 feet above the sea; Livonia, 1,025; Elk River, 975; Blue Hill, 1,025; Orrock, 980; Big Lake, 940; Santiago, 1,025; Becker, 1,000; Palmer, 1,020; Clear Lake, 980; and Haven, 1,010. The mean elevation of Sherburne county, according to these estimates, is 1,000 feet above the sea-level.

Soil and timber. The fertile black soil in this district has generally a thickness of about one foot; and below this the subsoil in Benton county is mostly the clayey till, and in Sherburne county the sand and gravel of the modified drift.

Heavy timber covers the greater part of Benton county, and is found in Sherburne county along the rivers and on an area of slightly undulating till covering several square miles in Livonia township. White pine occurs rarely on the bluffs of the Mississippi river, and at a few localities northward through these counties; but it becomes abundant, being often the principal forest tree in the northeast portions of Alberta and Maywood, which lie on the southwestern limit of the pineries of northern Minnesota. Sugar and white or soft maple, basswood, bur and black oaks, ironwood, yellow birch, poplar, and wild plum, wild red cherry, and Juneberry, are plentiful in the heavy timber; black and white ash, butternut, canoe birch and balsam poplar are frequent; tamarack is common in swamps; box-elder, wild black cherry, hickory, cottonwood and red cedar are rare, the two latter being found occasionally beside rivers and lakes. The shrubs include prickly ash, hazelnut, choke-cherry, red and black raspberries, high blackberry, prickly and smooth gooseberries, black currant, wolfberry, sheep-berry, bush cranberry, low blueberries, staghorn and smooth sumach, frost grape, Virginia creeper, climbing bitter-sweet, alder and low birch.

Much of Sherburne county is thinly wooded with black and bur oaks. The trees are often scattered, and the open spaces are covered by dwarf oaks, hazelnut and other bushes, such tracts being called "oak openings." More rarely trees are absent, though shrubs cover the ground, when it is denominated "brush prairie."

True prairies of natural grassland, without trees or shrubs, are found along the Mississippi river, occupying the greater part of the area between that and the Elk river in Sherburne county, and most of the western two-thirds of Langola and the northwest part of Watab in Benton county, the latter tract being named Rice prairie. St. George prairie in the south part of Minden covers nearly five square miles, lying west of Elk river and south of Mayhew creek; and Craig prairie in the west half of Orrock has an area of about two square miles.

GEOLOGICAL STRUCTURE.

Archæan rocks.

All the outcrops of rock found in these counties belong to the Archæan age. They occur in the west part of Haven, the most northwestern township of Sherburne county, and in Sauk Rapids, Watab, Gilmanton and Alberta in Benton county. This district is part of a broad belt of crystalline rocks of Archæan age which reaches from their great area in Canada and northern Minnesota southwest to the Minnesota river. In these counties and in Stearns county, lying next west, this belt consists mainly of syenite, which differs from true granite in containing the mineral hornblende instead of mica, both being otherwise alike composed of quartz and feldspar. The three ingredients of each occur in crystalline grains; and no schistose or laminated structure, and consequently neither dip nor strike, are observable. The common species of feldspar present is orthoclase. Valuable quarries of this syenite, commonly called "granite," are worked in the townships of Haven, Sauk Rapids and Watab, all bounded by the Mississippi river on the west.

Haven. The most southern rock-outcrop observed in these counties is in the S. ½ of the S. W. ¼ of section 17, Haven, four miles southeast of Saint Cloud, and about two-thirds of a mile west of the Saint Paul, Minneapolis &

Manitoba railway. It is owned by Robbers & Barthelemy, and was by them leased in May, 1881, for two years, with privilege to extend the lease three years more, to the firm of Saulpaugh & Co., of Rock Island, Illinois, contractors for building the bridge for the Northern Pacific railroad across the Missouri river at Bismarck. They have also leased quarries in Watab for this bridge, which in its abutments and four piers requires 7,000 cubic yards of cut stone. The outcrop has an area of four or five acres, being about thirty rods across, and rises with a rounded, smooth surface of bare rock ten to fifteen feet above the surrounding prairie of nearly level modified drift. Hence it is often called the "rocky island" or "rocky point." About ten rods west of the main outcrop is another of small extent. This rock is a coarse-grained syenite, of whitish gray color, with dark blotches of hornblende. It is evidently a stone of great strength and durability. The first quarrying at this point was by Daniel Burns, of Sauk Rapids, in 1879, supplying stone, some 600 cubic yards, at price of about $9,000, for the Mississippi river bridge of the Chicago, Milwaukee & Saint Paul railway on the short line between Saint Paul and Minneapolis.

Two miles north from the foregoing and the same distance southeast from Saint Cloud, are the quarries of Breen & Young, situated close west of the railroad, nearly on the line between the S. E. ¼ of section 6 and the N. E. ¼ of section 7, Haven. The rock here has frequent exposures along a distance of nearly a half mile from the quarry, to the southeast and northwest, rising five to twenty feet above the adjoining marshy lowland. On the south and southwest side it is covered by morainic drift, which forms a ridge 40 to 50 feet high and of irregular contour, reaching from the railroad westward through section 7. Most of these ledges are a gray syenite of fine grain and uniform texture, well suited for building purposes. It is used in the corners, steps and trimmings of the United States custom house and post office in Saint Paul. Breen & Young employ about twenty-five men here in quarrying. The greater part of their stone-cutting, especially for ornamental work, is done in their shops at Saint Paul. Their quarry has been wrought since 1868; the extent of the principal excavation is about 250 by 200 feet, and its depth is mostly from four to six feet. About thirty rods west of this opening is an area of reddish syenite, which has been slightly quarried. The same color is also seen in small outcrops a sixth of a mile farther north beside the railroad.

Sauk Rapids. This township has many outcrops of rock. The quarry which has been longest worked and yields the best stone, a fine-grained gray syenite, especially adapted for ornamental use and for cemetery monuments, is situated nearly in the centre of the village of Sauk Rapids. It was first opened by Mr. F. A. Fogg, in May, 1867, and was worked by him four years. It is now owned by Collins, Mitchell & Searle, of Saint Cloud, and within the past three years has been leased and worked by Messrs. Burns, Reeder and Robinson, who cut and polish the stone near the quarry. The excavation is about 150 by 100 feet in extent, and five to seven feet deep. The sales are about $2,000 annually, and have varied from $500 to $10,000 a year. In Minneapolis the towers of the suspension bridge and the city hall are trimmed from this quarry, the rest being Trenton limestone. In Saint Paul the wholesale hardware store of Nicols & Dean is built from this quarry, except the columns and buttresses, which are from Watab. In Milwaukee this quarry supplied the polished front of the Mitchell Bank building, some of the slabs used being 11 feet by 3 by 1 foot in dimension. The Iowa state capitol at Des Moines, recently built, took part of its stone for trimmings from here, some of the pieces measuring 10 by 2½ by 2 feet. This syenite is closely like that of Breen & Young's quarry in Haven.

A coarser syenite is exposed about a quarter of a mile farther west, at the east end of the Sauk Rapids bridge and dam, which are founded in part upon this rock. Its outcrop, coarsely porphyritic, a few rods south of the west end of this bridge, is described in the next chapter, with the other rock exposures of Saint Cloud, Stearns county.

The fall in the Mississippi here in about one mile, from the mouth of the Sauk river to Maple island is 22 feet, from 992 to 970 feet above the sea. Its channel is strown with boulders, but has no extensive exposures of solid rock.

About a mile east from Sauk Rapids, in the N. W. ¼ of section 24 of this township, an outcrop of reddish, rather fine-grained syenite occurs in a swampy depression, some twenty-five rods south of the Gilmanton road. Its area reaches about twenty rods from north to south and is about ten rods wide, with a hight of two to five feet. This rock is traversed by joints from one to ten or fifteen feet apart. Its surface is smoothly glaciated, but retains no striæ.

An exposure of gray syenite occurs in the S. W. ¼ of section 13 of this township, on land of Robert W. Leyerly. Its extent is about 50 by 30 feet, with hight of three feet above the adjoining marshes. It is crossed by joints two to eight feet apart.

In the N. W. ¼ of section 13, on land of the E. D. Learned estate, a coarse-grained reddish syenite, with large proportion of feldspar, covers an area thirty rods or more in length toward the west-northwest, averaging eight rods in width. Its higher portions are four to seven feet above the marsh which mainly surrounds it. This rock is very massive, extending in some places thirty to forty feet without a joint. It is cut by a trap dike, the ordinary dark and tough doleryte, one to one and a half feet wide, and reaching within view about fifty feet from east to west.

Extensive outcrops, partly of coarse-grained reddish syenite, and partly of finer-grained gray syenite, of which the latter has been considerably quarried, occur on the N. E. ¼ of section 14, on land of Joseph Moody; covering some thirty acres and rising 25 feet above the adjoining swamps, or 75 to 100 feet above the Mississippi. This rock is mostly divided by joints from six inches to five feet apart.

Syenite nearly like the coarse reddish portion of the last or that described in the N. W. ¼ of section 13, occurs also at several places in the S. E. ¼ of section 11, on land of William Kouts. Its most northerly exposures are about sixty rods north of the south line of the section, and do not rise above the general level of the surrounding marshy land. A smooth surface of this rock, about fifty feet across, being the largest patch seen here, has no joint or seam. An outcrop of this rock about a hundred feet square, lying some forty rods south-southwest from this, upon the same quarter-section and three to ten rods north of its south line, rises five feet above the general level and is divided by joints three to eight feet apart, mostly running north and south, with others less numerous from east to west.

In the N. E. ¼ of the N. W. ¼ of section 11, owned by Collins, Mitchell & Searle, and in the adjoining N. ½ of the N. E. ¼ of the same section, owned by E. E. Beal, are large exposures of red syenite, which has been quarried somewhat. This syenite covers about ten acres, and rises ten to twenty feet above neighboring depressions. At the quarry it is distinctly red near the surface, but gradually changes to gray at a depth of three or four feet. It is rather coarse in grain. Feldspar, quartz and hornblende are all present in considerable amount, the feldspar being about half of the whole. This rock is very massive, sometimes extending a hundred feet without a joint. The distance to the railroad is one and a half miles, and to Sauk Rapids, two and a half miles.

Watab. The southern two-thirds of this township, to a distance of three miles from the Mississippi, has many outcrops of these crystalline rocks, mainly of syenite, which presents varieties similar to those described in Sauk Rapids.

In the N. W. ¼ of section 35, about one-third of a mile east of Watab station, is the quarry of Talcott, Castle & Co., which was worked by them in 1871 with forty men, drawing the stone six miles to Sauk Rapids, then the end of the railroad. This stone was mostly used for buildings in Chicago, which were destroyed in the great fire of October, 1871. It has been much used for cemetery work, as monuments and bases.

About a half mile farther east, in the N. E. ¼ of this section 35, is the quarry owned by H. D. Gurney, of Saint Paul, which was opened and considerably worked in 1874 and 1875. From that time it remained idle till 1881, when it was leased to Saulpaugh & Co., by whom it was operated with from fifty to a hundred men, including quarrymen and cutters, the stone being used, with that quarried by them in Haven, as before stated, for the Northern Pacific bridge at Bismarck. This exposure includes three distinct varieties of syenite: gray, coarse-grained, which makes up the greater part of the stone quarried; gray, finer-grained; and reddish, with grains of intermediate size. These kinds of rock lie in contact, showing, at least in some portions of the quarry, no gradual transition but an abrupt change at a definite line. A branch track, a mile in length, was laid from the railroad to this quarry in May, 1881.

Extensive ledges of similar rock lie in the S. E. ¼ of section 36.

In the north part of section 34, on land of Joseph Campbell, are also large exposures of syenite of excellent quality, but not yet quarried, except to supply a block 3 by 1½ by 1 foot in size, polished on one side, which was sent to the Centennial Exposition.

The highest points of the foregoing ledges rise 10 to 20 feet above the average of the adjoining land, or 75 to 100 feet above the Mississippi river which here is 1,000 feet above the ocean.

Prominent knobs of syenite, mostly reddish and somewhat porphyritic, and often darker and finer-grained than the preceding, sometimes in appearance approaching trap, dikes of which are also present, occur in section 27, between the railroad and the river, a half to one mile north from Watab station. At each side of the river road its elevations are 40 feet above the road and 75 to 90 feet above the river. One of these hills of rough, bald rock (called by Schoolcraft the *Peace rock*) rises in moderate slopes directly from the river's edge about a half mile south from the mouth of Little Rock creek, which was so named because of these ledges.

Prospecting for gold was undertaken here, some fifteen years ago, by Major T. M. Newson, sinking a shaft about ten feet. This is close southeast of the river road, near the centre of section 27. It is some 40 feet above the river, with a depression on the east, separating it from a hill about 75 feet high a sixth of a mile east. The vein explored is quartz, one to eight inches thick, dipping 80° S. E. The east wall of this vein is dark and tough trap; and its west wall is a porphyritic, reddish syenite.

A small outcrop, twenty-five or thirty feet across and some 15 feet high, lies in the N. W. ¼ of section 26, a short distance east from the railroad and highway. Beyond this, northward, the only other rock-exposure known in this county near the Mississippi river is a small and low outcrop in its bank, of a tough, close-grained, hornblendic rock, occurring about a mile farther north, opposite the northeast corner of section 33, Brockway, Stearns county.

Gilmanton. The only ledges that remain to be described in Benton county are in its central and northeastern portions, within Gilmanton and Alberta townships.

In the S. E. ¼ of the S. W. ¼ of section 18, Gilmanton, on land of Clement Teller, about twelve rods west of the road, reddish syenite, mostly in large fractured blocks, is exposed at the south side of a small brook, upon an area two or three rods in extent.

About three-fourths of a mile west from this, similar rock is said to outcrop on the east side of the Elk river and in its channel, rising about ten feet above the river and extending six or eight rods.

Alberta. At the end of the portion of the old state road which had its timber cleared off, this being at the middle of the north side of section 20 in the east township of Alberta, the most northeastern of the county, this road crosses an exposure of rock which has an extent of about twenty-five rods from north to south, and is some fifteen rods wide. The quarter-section stake is about five rods east from the north part of this ledge, which extends into the edge of section 17, but lies mainly in the N. E. ¼ of the N. W. ¼ of section 20, on land of Charles A. Gilman, of Saint Cloud. The northeast part of this outcrop contains a dike of trap, dark with whitish spots, seen along a distance of thirty or forty feet and varying from eight to eighteen inches in width. Its course in the east part of its visible extent is S. 60° W.; but it is changed beyond to about due west. South of this dike the rock is a coarse-grained, reddish syenite, composed mostly of feldspar, with perhaps one-fourth part quartz. On the north side of the dike the texture of the rock is very different, though its mineral composition may be nearly the same. Here it is very fine-grained, and is much more traversed by joints, which are usually only one to two feet apart, dividing the rock into rhomboidal masses. These diverse rocks, definitely divided at this dike, appear to form respectively the south and north parts of this outcrop. Other ledges of syenite are reported within a mile northward, in section 17 and the N. E. ¼ of section 18.

About four miles east from the last, in the N. W. ¼ of section 24 of the same township, several exposures of coarse-grained reddish syenite occur in the banks and bed of the West branch of Rum river. In proceeding eastward and down the stream, the first of these outcrops is about twenty-five rods above the new "roll dam," which was rebuilt in 1879. At this upper ledge wings of logs are built on each side to turn the floating logs into the middle of the stream, which here falls three feet, the open space between the wings being thirty feet. The channel here and both banks to a hight one or two feet above the water, along a distance of twenty or thirty feet at each side, are of this syenite, but it has no exposures upon the general surface, which is elevated only about five feet above the stream. The crystals of this rock are an eighth to a half an inch long; about two-thirds of the whole consist of flesh-colored feldspar; about one-sixth is quartz, varying from whitish to smoky and transparent; and the remainder consists of dark particles, mostly hornblende, with rare grains of black mica.

At the "roll dam," twenty-five rods northeast from the last, the same rock is exposed in the south or right bank, and the south half of the dam for about seventy-five feet is founded on it. Its width visible is from ten to twenty-five feet, and its hight above the water below the dam is one to two feet. The fall here is also about three feet. Both these outcrops are massive, often showing no joint for twenty or thirty feet.

At a bend in the river about thirty rods below, being northeast and within sight from the "roll dam," the northern or left bank has an exposure of this coarse syenite, about twenty-five feet long and five to fifteen feet wide, rising one foot above the water; succeeded in the next twenty-five feet east by a very fine-grained, compact, but considerably jointed rock, of deep dull red color, apparently made up mainly of feldspar. Its extent seen was about twenty-five feet long by five to ten feet wide, reaching one foot above the water, which at the time of this examination was probably two feet above its lowest stage.

Within sight from the last and about a dozen rods down the stream, which here flows to the southeast, the coarse-grained massive syenite is again exposed in the northeast or left bank of the river. Its extent is about 50 by 10 to 20 feet, and its hight was two feet above the water, to which this ledge descends perpendicularly, with deep water at its side.

These are the first ledges found by lumbermen in descending the West branch of the Rum river.

Glacial and modified drift.

Glacial striæ were observed at several places on the syenite in the N. E. ¼ of section 14, Sauk Rapids, bearing S. 45° to 50° W., referred to the true meridian. At another point, a few rods from these, their course is S. 15° W. Glacial striæ, seen at a dozen places on the ledges in the north part of section 11, Sauk Rapids, bear quite uniformly S. 50° W., varying rarely to S. 45° W. and S. 55° W. They were also found near the quarry of Talcott, Castle & Co., in section 35, Watab, bearing S. 15° W. The other rock-outcrops in these counties are smoothly planed and rounded by glacial erosion, but their striæ have been generally effaced by weathering.

All of Sherburne county excepting its western extremity, and the greater part of Benton county, are so deeply covered by the drift that they have no exposures of the bed-rocks. Under the head of topography in a former part of this chapter, the contour of the drift-sheet, in its divisions of undulating till, morainic hills of till and modified drift, and its extensive nearly level areas of modified drift, has been described, with the limits of these various deposits.

Their relationship to each other in their manner and time of deposition, and the sequence of events in the glacial period and especially in the recession of the last ice-sheet indicated by these drift formations, remain to be noticed briefly here.

The reader is referred to the last chapter for an account of the glacial movements from the northeast and from the northwest and west; the character of the drift brought by each; the extension of the drift from the west over that from the northeast; successive morainic belts formed at lines of halt or temporary re-advance during the final melting and retreat of the ice; and the origin of the modified drift from material contained in the ice-sheet and finally exposed on its surface, whence it was washed away by the streams and floods produced in its melting and deposited from them on the areas of plain and in the valleys along their course from the ice-sheet to the sea. The till of Benton county, excepting the upper part in the southeast corner of the county, is of northeastern origin, as shown by boulders from the region of lake Superior and by the absence of limestone. The proportion of its material derived from the distant red shales and sandstone of lake Superior is not so great, however, as to give it everywhere a distinctly reddish color, and it is in some portions yellowish near the surface and dark bluish below nearly like the till brought by the ice-current from the northwest. It was seen to have a plainly reddish hue in excavations at Sauk Rapids, in section 30, Minden, and at the west end of the mill-dam in section 10, Santiago.

Low morainic hills and ridges of till with many boulders on Stony brook near the east line of Alberta, and a belt of somewhat morainic drift continuing thence southwest through Maywood and into the east part of St. George, with the series of low hills and ridges of till extending from the northwest part of Palmer through northern Haven to the Mississippi river one to two miles south of East Saint Cloud, are together referred to the time of the fifth or Elysian moraine, and are believed to have been accumulated then along the southern boundary of the ice flowing from the northeast and north. This view makes them contemporaneous with the moraine formed in the north part of Chisago and Isanti counties on the northern border of the ice-flow from the west, and the westward continuation of that moraine seems to be represented in Sherburne county by the Blue mound and the morainic tract in Becker township. The angle of confluence of the portions of the ice-sheet moving from the northeast and from the northwest was probably at this time near the southeast corner of Wakefield in Stearns county.

Kames were formed in Orrock and the north part of Elk River during the recession of the western ice-lobe from Blue Hill and Becker south to the conspicuous drift-hills that reach from east to west across the central part of Elk River township, supposed to belong to the time of the sixth or Waconia moraine. At this stage in the recession of the ice-fields, their northeast portion probably terminated at a line reaching southwesterly across Benton county to the vicinity of Watab and Sauk Rapids, and the angle of confluence of the northeastern and northwestern ice-flows was near Glenwood in Pope county. The modified drift covering Sherburne county was mostly deposited during the glacial recession from the Elysian to the Waconia moraine, and during the time ensuing in which the latter moraine was accumulated. The floods from the glacial melting upon large districts farther west found passage eastward over this area, beyond which, in Isanti and Anoka counties, they flowed south to the Mississippi. Later stages in the retreat of the ice uncovered northwestern Benton county, and were attended with the deposition of the modified drift forming Rice prairie in Langola and Watab.

Boulders. Occasional pieces of limestone, from the size of gravel to slabs or blocks ten feet long, occur in the morainic drift of Becker and Elk River townships. Most of the boulders in both these counties are syenites, granites and crystalline schists. In size they are mostly less than five feet in diameter, and boulders more than ten feet in diameter are very rare. One of the largest found in Minnesota is the "big rock," situated on land of Peter E Clarity, in the N. W. ¼ of the S. W. ¼ of section 7, Palmer. The dimension of this mass is about 20 by 35 feet, and its hight is 20 or 25 feet. It probably also reaches several feet below the surface, from which it rises perpendicularly on all sides. This boulder is dark mica-schist, varying to gneiss, coarsely laminated, with much black mica and many minute garnets, and containing in some portions whitish feldspathic layers from a quarter of an inch to two or three inches in thickness. From it numerous fragments, three to ten or twelve feet long, have been riven off by frost, especially on its northwest side. It lies on a southwesterly sloping swell of morainic till.

Mr. O. E. Garrison, of Saint Cloud, has mapped the course of an interesting ancient channel of the Mississippi river, diverging from the present channel in the south part of Sauk Rapids village and extending southeastward six miles to Elk river at the east side of section 15, Haven. Its position and its width, which varies from twenty-five or thirty rods to nearly a mile, are shown on plate 46 by the contour line of 1,000 feet. This is a notable topographic feature, being a flat-bottomed hollow, mostly occupied by marsh, 15 to 25 feet lower than the level prairie of modified drift on its southwest side, and bordered on the northeast where it crosses the line between Sauk Rapids and Minden by a bluff of till 30 to 50 feet high. Its widest portion is in section 5, Haven, next to the northeast of Breen & Young's quarry. This old valley is one of the incidents of the flooded stage of the Mississippi during the last ice-age, and is similar to that seen running parallel with the Minnesota for some miles in Chippewa county. The obstructions of the current caused by the rocky outcrops at Sauk Rapids set back the water till a part of it found means of exit through this easterly channel. On the removal of the obstructions, and the shrinkage of the river, this old channel was abandoned permanently.—N. H. W.

Wells in Benton county.

Alberta. John Lobdell; sec. 18 of the east township: well, 15 feet; soil, 1; yellowish till, picked, 12; sand and gravel, 2 feet and extending deeper; water rose seven feet in one day. This and other wells in this region and throughout the part of the state farther northeast obtain soft water, suitable for washing with soap. The hard water of wells in the southeast part of Benton county, in Sherburne county, and throughout southern and western Minnesota, is due to the carbonates of lime and magnesia held in solution, derived from the limestone, much of it pulverized, which there forms part of the drift.

Nelson Orcutt; N. E. ¼ of sec. 22 of the west township: well, 27 feet; soil, 1; yellow till, picked, 19; darker bluish till, somewhat harder, 7 feet, containing two or three layers of dark sand, three to eight inches thick; water seeps, becoming ten feet deep.

Maywood. A. P. Shaw; S. W. ¼ of sec. 32: well, 25 feet; soil, 2; yellowish till, picked, 23; hard water seeps near the bottom, filling the well to the depth of six feet. Wells in the south part of this township and in Glendorado and the southeast part of St. George generally have hard water.

Gilmanton. E. N. Demick; sec. 7: well in reddish till, 27 feet, to sand and gravel, 1 foot or more, from which water rose in two or three hours to be four feet deep.

Daniel Walker; N. W. ¼ of sec. 8: well, 28 feet, all the way in yellowish or somewhat reddish till, which contains a very hard and more gravelly layer one foot thick at the depth of thirteen feet; water seeps from a crevice in the till seventeen feet below the surface, not accompanied by any layer of sand or gravel, and fills the well twelve feet.

Asher Walker; sec. 10: well, 13 feet; till, 11; yellow sand, 2 feet and continuing lower, from which water rose six feet.

Thurston De Long; N. W. ¼ of sec. 18: well, 12; soil, 1; yellowish and reddish till, very hard, requiring to be picked, for all below; water seeps from a crevice in the till. These and other wells in Gilmanton have soft water.

St. George. John Fothergill; sec. 29: well, 36 feet; soil, 1; coarse gravel, up to one foot in diameter, 4; yellowish till, 20; bluish till below, somewhat harder, 11; water seeps from the bottom, becoming one and a half feet deep. A layer of dry sand was noted in the till in this well some twenty feet below the surface, dipping about 10°.

Christopher Blattner; N. W. ¼ of sec. 32: well, 45 feet; soil, 2; yellowish till, very hard, 8; yellow sand, 6; till again, 10; and very coarse gravel with rounded stones up to five feet in diameter in its upper half, less coarse below but very stony with cobbles to the bottom, 19 feet; water, though only two feet deep, comes in an inexhaustible supply.

Langola. At Rice's station wells are 20 to 30 feet deep, all being sand and fine gravel.

D. W. Broadhead's well in the S. E. ¼ of sec. 11, T. 38, R. 32, close south of the lower bridge on the Platte river, is 36 feet deep being soil, 2; sand, 4; yellowish till, 26; and sand and gravel, 4 feet; with water.

At the school-house in the northeast corner of the S. E. ¼ of sec. 11, T. 38, R. 31, the well is also 36 feet deep, being sand and gravel, 4 feet; and yellow and red till, 32; water seeps, becoming five feet deep.

J. W. Joslyn; N. W. ¼ of sec. 6, T. 38, R. 30 (the east township of Langola): well, 18 feet; soil and yellowish loam, 3; yellowish till, picked, 15; water comes in a thin layer of quicksand at the bottom, rising three feet. Generally the wells in till in this township obtain soft water, suitable for use with soap; but in some instances, as Mr. Joslyn's, they have hard water, so made by infiltration through the modified drift spread over western Langola and a wide belt extending thence northward, which contains some proportion of limestone gravel and sand.

Watab. Joseph Campbell; N. E. ¼ of sec. 34, in the southwest part of the township: well, 12 feet; soil, 2; till, 10, with plenty of water. On Mr. Campbell's farm in the S. W. ¼ of sec. 8, on the northwest side of Mayhew lake, a well 35 feet deep in soil, 2; with yellowish and bluish till, so hard as to require to be picked, for all below; the only water obtained is from a seam of gravel and sand in the till, six inches in thickness, nine feet below the surface.

Minden. Roger Bell; sec. 28: well, 30 feet; all gravel and sand.

W. H. H. Stevens; also in sec. 28; well, 24; soil, 2; sand and gravel, with water, 17; and yellow clay, said to contain no gravel, 5 feet and lower.

B. F. Shaw; sec. 30, on the west edge of the St. George prairie: well, 30 feet; soil, 2; gravel, 8; yellowish till, picked, 20; water seeps.

Sauk Rapids. Philip Beaupre; sec. 15; well, 33 feet, all yellowish or gray till, picked; water rose three feet from sand at the bottom.

Wells in Sherburne county.

Baldwin. Edward Pierson; sec. 12: well, 24 feet, all sand and fine gravel.

Livonia. B. N. Spencer; N. E. ¼ of sec. 26: well, 53 feet; soil, 2; coarse sand with gravel, becoming more and more gravelly below, there containing rounded stones up to five or six inches in diameter, 51 feet, to water.

Solon B. Heath; N. W. ¼ of sec. 34: well, 95 feet; soil, 1 foot; yellow gravel and sand, containing rounded stones up to six or eight inches in diameter, 25 feet; sand, with occasional layers of fine gravel, mostly yellowish, 50 feet; quicksand, light yellowish, 4 feet; sand, 13 feet, containing a layer of whitish clay four inches thick; and blue clay, thought to contain no gravel, 2 feet and continuing deeper; water comes from the quicksand at 76 to 80 feet.

Elk River. G. B. Upham's well, in the village, is 43 feet deep; soil, 1; sand and gravel, 40; and coarse gravel, 2; the water fluctuates in hight with that of the Mississippi river.

Blue Hill. Most of the wells in this township are 15 to 20 feet deep, finding only sand and gravel. L. H. Pratt's well, in sec. 8, is 14 feet deep in reddish till, from which water seeps.

Big Lake. Wells on the plain of modified drift south of the Elk river, are 15 to 20 feet deep, in sand and gravel.

Santiago. O. L. Bailey's mill, in the N. E. ¼ of sec. 10: well, 16 feet deep, in reddish till. Wells in this vicinity range from 15 to 25 feet in depth; they are often in part or wholly gravel and sand.

Becker. Wells at Becker station are 25 to 30 feet deep, all the way in sand and gravel. The three following are on the morainic area in this township, and show that it consists of red till overlain by blue and yellow till.

Andrew Knutson; W. ½ of the S. E. ¼ of sec. 8: well, 42 feet; all till, yellowish above, reddish below, requiring to be picked, excepting a more gravelly portion about five feet thick, 20 to 25 feet from the surface. This till throughout contains much gravel and sand, with a less proportion of clay than usual.

J. P. Anderson; sec. 18: well, 26 feet; soil and sand, 2 feet; and till, 24 feet, yellowish above and reddish below, so hard that it requires to be picked, but containing much gravel and sand; water three feet deep.

J. H. Shepardson; S. ½ of the N. W. ¼ of sec. 30: well, 35 feet; soil, 1; sand 10: yellow and blue till, 24 feet, all picked, harder and more stony in its lower part; a layer of dry white sand 1 to 1½ feet thick was found in this till 25 feet below the surface.

Palmer. Wells in this township are mostly 15 to 25 feet deep, in sand and gravel.

Clear Lake. The railroad well at the station is 37 feet deep; soil, 2; sand and fine gravel, 18; and red till, picked, 17; water rose seventeen feet from sand at the bottom in twelve hours. Wells a mile farther east are 25 feet deep, wholly in sand and gravel.

Haven. Peter E. Clarity; sec. 12: well, 19 feet; soil, 1; sand and gravel, 6; very compact iron-rusted gravel, 2; yellowish till, picked, 6; blue till, 2; yellowish gravel, 2 feet and extending lower; water three feet deep, impregnated with iron, so that it deposits iron-rust on the trough in which it is held.

J. O. Cater; sec. 27: well, 24 feet; soil, 1; sand and gravel, 23 feet; water three feet deep. A driven well here reached clay, probably till, at 26 feet.

MATERIAL RESOURCES.

The agricultural capabilities of the soil in this district, and the value of its timber for manufactures and fuel, are its chief natural resources.

Water-powers. Numerous water-powers are already utilized, and many others lie unimproved.

On the Mississippi river at Sauk Rapids the Eagle flouring mill, owned by J. A. Stanton, has a head of eight feet. Below this mill the river falls fourteen feet in the next mile.

The Platte river falls thirty feet in three miles from the railroad bridge to its mouth.

George T. Rice's saw-mill on Little Rock creek, one mile northeast from Rice's station, has a head of ten feet.

C. C. Holmes' saw-mill on Elk river, in the S. E. ¼ of section 26 in the southwest part of Gilmanton, has about six feet head. Basswood, oak and maple are sawn for wagons and furniture.

A flouring mill has been recently built on Elk river near Bailey station, about four miles above its mouth.

The Elk River mills on this stream about one mile from its mouth are owned by Mills & Houlton; head, eight feet; the dam is submerged at times of high water in the Mississippi river.

There was formerly a water-power saw-mill on the St. Francis river in section 31, Maywood.

O. L. Bailey's saw-mill, manufacturing felloes for wheels, on the St. Francis river in the N. E. ¼ of section 10, Santiago, has nine feet head.

Building stone. Quarrying is an important industry in Haven, Sauk Rapids and Watab. Details concerning these rock-outcrops and quarries have been given in a preceding part of this chapter.

Lime. No lime-burning is done in this county, but limestone boulders gathered from the morainic hills in Elk River are burned for lime in the adjoining township of Burns, Anoka county.

Bricks. Red bricks of inferior quality being easily broken, have been made since 1875 by Charles Nowach at the north end of Eagle lake in section 30, Orrock; yearly product, 20,000 to 30,000, sold at $5 per thousand.

Red bricks, said to have been of good quality, were also made about fifteen years ago in the east part of Baldwin.

Springs occur numerously in this district, especially along the valleys of streams. Several notable springs are found on the west shore of Briggs lake in Palmer, and the stream flowing into the north end of this lake is so impregnated with iron that wood and stones in its channel become coated with iron-rust. In section 25 in the southwest part of Gilmanton, springs produce a large brook which does not freeze in winter and is cold all summer. A copious chalybeate spring issues from the west bank of the St. Francis river about twenty rods below the place of the former mill-dam in Maywood, being in the S. E. ¼ of the S. E. ¼ of section 31.

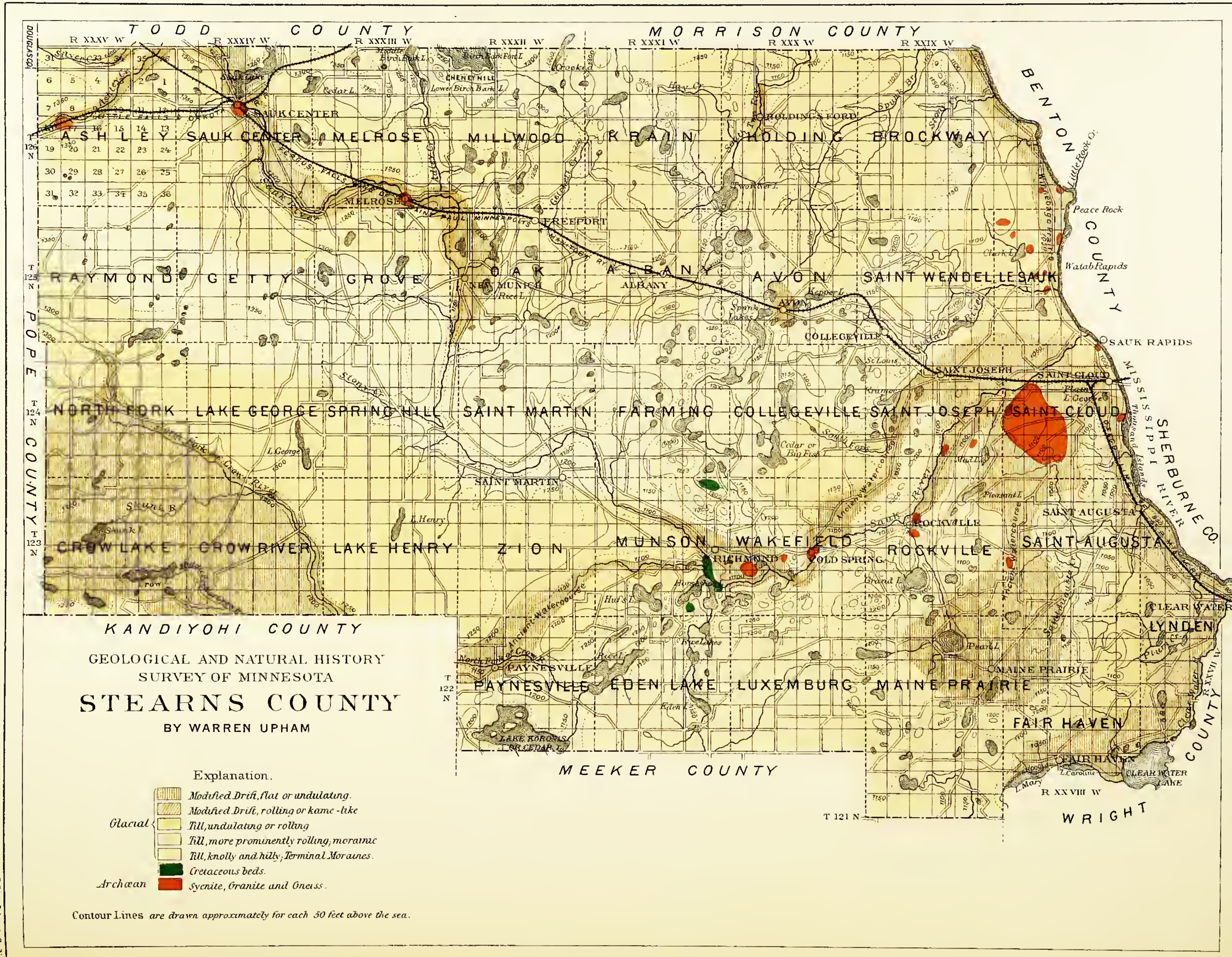
ABORIGINAL EARTHWORKS.

An artificial mound of the usual round form, three feet high, was seen about twenty-five rods south of the highway bridge over Little Rock creek in Watab, between the road and the creek. Several mounds are reported on the east side of the north part of Little Rock lake.

Mounds three or four feet high occur on the S. E. ¼ of section 2, the N. W. ¼ of section 8, and the N. W. ¼ of section 10, Gilmanton.

On the northwest side of Elk lake in the east part of section 33, Palmer, is a mound about fifteen feet high. This is on land of Fred Thomas. On the southeast side of this lake northward from its outlet, in the east section 3 of Clear Lake township, is a series of many round mounds two to four feet high, extending about a quarter of a mile.

A mound about fifteen feet high, situated west of the south part of Eagle lake, in the N. W. ¼ of section 6, Big Lake township, was partially excavated by Mr. G. W. Knowlton and others, finding several skeletons.



Julius Bien & Co. lith.

CHAPTER XVI.

THE GEOLOGY OF STEARNS COUNTY.

BY WARREN UPHAM.

Situation and area. Stearns county (plate 47) is situated a short distance south of the centre of Minnesota, on the west side of the Mississippi river. It is the largest county in the south half of the state. Saint Cloud, its largest town and county seat, is about sixty and seventy miles northwest, respectively, from Minneapolis and Saint Paul. Sauk Center, the second town in importance, is forty miles west-northwest from Saint Cloud. Other towns and villages of considerable size are Saint Joseph, Avon, Albany, Freeport and Melrose, on the Saint Paul, Minneapolis & Manitoba railway; New Munich, Saint Martin, Richmond, Cold Spring and Rockville, on or near the Sauk river below Sauk Center and Melrose; Saint Augusta, Clearwater (at the mouth of Clearwater river, mostly in Wright county), Fair Haven and Maine Prairie, in the southeast part of the county; and Paynesville, on the North branch of the Crow river.

The length of Stearns county from east to west, measured from Clearwater to its west line, is fifty-two miles; and its width is from twenty-five to thirty-four miles. Its area is 1,330.07 square miles, or 851,241.36 acres, of which 37,021.27 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county is drained to the Mississippi river by the following tributaries, arranged in their order from north to south: the South branch of Two rivers, Spunk brook, Watab river, Sauk river, St. Augusta creek, Clearwater river, and Crow river. The largest of these is the Sauk river, whose basin includes about half of this county, its principal affluents being Adley and Getchell creeks from the north, and Silver, Ashley, Stony, Cole and Mill creeks from the south. The North branch of Crow river drains the southwest part of the county.

Lakes. Eighty lakes equaling or exceeding a half mile in length appear on the map, and about a hundred and twenty-five of smaller size. The most noteworthy are Sauk lake, crossed by the north line of Sauk Center; Birch Bark Fort lake, on the north line of Millwood; Two River lake, in the southwest corner of Holding; the Spunk lakes in Avon; Cedar or Big Fish lake in Collegeville; lake George, Crow lake, lake Henry and Eden lake, which give names to townships; lake Koronis in the south part of Paynesville; Grand lake in Rockville; Pearl lake in Maine Prairie; and Clearwater lake, through which the Clearwater river flows a few miles east of Fair Haven.

Topography. Though Stearns county contains numerous rock-outcrops, these rarely form conspicuous elevations, and the contour is due almost wholly to the overlying deposits of glacial and modified drift. Glacial drift or till is spread with a moderately undulating or rolling surface on the area between the Sauk river and the North branch of the Crow river northwest from Richmond and Paynesville. Its elevations here are 10 to 30 or 40 feet above the lakes and small streams; but its general hight above the rivers on each side is 75 to 100 feet southeastward, decreasing to 40 or 50 feet in the west part of the county. Its most rolling portion extends from west to east through Raymond, Getty and Grove townships. With this area should be included also the undulating and rolling till, having similar contour and average hight, on the northeast side of the Sauk river in Saint Martin, the western two-thirds of Farming, Albany, except its eastern edge, the southwest part of Krain, and the southern half of Millwood and Melrose. The greater part of North Fork, Crow Lake and Crow River townships, southwest from the North branch of the Crow river, are nearly level or only slightly undulating gravel and sand of the modified drift, 10 to 20 feet above the lakes, sloughs and water-courses; but sections 31 to 34 on the southern border of Crow Lake are chiefly kame-like knolls and ridges of gravel and sand 25 to 50 or 75 feet high. The remainder of this county is greatly diversified with partly undulating and partly knolly and hilly till, the latter being morainic accumulations, which on some areas have a very irregularly broken surface, though not rising to much hight, while elsewhere they form hills from 50 to 200 feet high.

Morainic hills, about 100 feet above the adjoining modified drift or 150 above the Mississippi river, occur one to three miles south-southwest of Saint Cloud and a mile west of the river. In the southeast part of Saint Joseph, about five miles farther west, a series of morainic deposits begins west of Mud lake, and extends thence along the southeast side of Sauk river to Rockville and Cold Spring. Northeast of Rockville it is separated from the Sauk river by a tract of nearly level modified drift averaging a half mile wide and about 25 feet above the river; and the width of this part of the moraine is about one mile, with elevations 50 to 75 feet above the adjoining country. Between Rockville and Cold Spring morainic till borders the Sauk river and occupies a width of three miles to the south, rising in hills 100 to 200 feet above the intervening hollows, attaining the greatest elevation, nearly 300 feet above the river, in section 36, Wakefield, and section 31, Rockville. Thence a low morainic belt reaches south through sections 6 and 7, Maine Prairie, and 13, 24 and 25, Luxemburg; next it extends east through Maine Prairie, forming conspicuous hills, about 150 feet high, in section 27; and from a point halfway between Maine Prairie and Fair Haven it turns northeastward, continuing through the north part of Fair Haven and into the southeast quarter of Saint Augusta. In the latter portion its elevations are 50 to 75 feet above the plain of modified drift, six miles wide, which occupies the northeast part of Maine Prairie and reaches thence northward in a continuous belt, nowhere less than a mile wide, through the west part of Saint Augusta and Saint Cloud to the Mississippi river. On the east it is separated from the Clearwater and Mississippi rivers by flat or moderately undulating modified drift one to two miles wide in Fair Haven and Lynden.

West from the high morainic hills in the southeast corner of Wakefield, a roughly broken belt of morainic till extends through the south edge of Wakefield and Manson and the north edge of Luxemburg and Eden Lake, thence southwest diagonally across Paynesville, and averaging one and a half miles in width, with elevations 50 to 75 feet above the hollows and 75 to 125 feet above the Sauk river, the North branch of the Crow river, and lake Koronis. South of this moraine, most of Luxemburg and Eden Lake, with the southeast edge of Paynesville are moderately undulating or rolling till; and on its northwest side a belt of nearly level modified drift, two miles wide and about 25 feet above the North branch of Crow river, extends from Roseville in Kandiyohi county northeast by the village of Paynesville to the head of Cole creek in sections 34 and 35, Zion.

North of the Sauk river, hills of morainic till, 100 to 250 feet high, extend northwest from a point one mile west of Cold Spring, through sections 21, 16, 17, 18, 7 and 8, Wakefield, and 12, 11, 2 and 3, Munson. They are very conspicuously seen from Richmond on the plain of modified drift one to two miles wide and five miles long, which lies southwest of this moraine between it and the Sauk river. Near the north line of Munson the moraine changes its course to the north-northeast, and passes through the east part of Farming and northwestern Collegeville to the Spunk lakes, forming a roughly hilly belt two or three miles wide, with elevations 100 to 150 feet above the smoothly undulating or rolling till on each side. Thence it continues north through the west part of Avon to Two River lake, consisting of hills and ridges 40 to 100 feet high, and northwesterly through Krain in a low knolly belt. Farther west, till with typically morainic contour extends from Birch Bark Fort lake through the north half of Melrose to Sauk lake. One of the more prominent elevations of this tract is Cheney hill, about 100 feet high, in the north part of section 1, Melrose. This moraine continues northward in Todd county.

Morainic till also extends from the Sauk river in the northwest part of Rockville northward through the west half of Saint Joseph, the east edge of Collegeville, and southeastern Avon; it occupies the southern third of Saint Wendel, west from the Watab river; and continues northeast in a belt one or two miles wide from sections 17, 18 and 19, Saint Wendel, to near the centre of Brockway, and thence north to the county line at the east side of Spunk brook. The elevations in these townships are 50 to 100 feet, or rarely more, above the adjoining land; in northwestern Rockville they rise about 150 feet above the Sauk river, and in northern Brockway their hight is fully 200 feet above the Mississippi. Nearly all of Holding township, northeastern Krain, the greater part of Brockway and Le Sauk, and much of the northern two-thirds of Saint Wendel and Avon, are moderately undulating till.

Level gravel and sand of the modified drift forms a belt a half mile to one and a half miles wide along the Mississippi river through Brockway and the north part of Le Sauk. Its broad southern portion, some three miles long, is the Winnebago prairie, about 40 feet above the river, but in the north part of Brockway its hight is 50 or 60 feet. Moderately undulating till borders the west side of the Mississippi from the mouth of the Watab river to Saint Cloud, soon ascending 40 to 60 feet and thence maintaining the hight westward. From Saint Cloud to Clearwater the Mississippi is again bordered by a plain of modified drift, which increases in this distance from a half mile to two or three miles in width and from 50 to 75 feet in hight above the river.

Along the Sauk river modified drift occupies a width that varies from a half mile to two miles through Sauk Center, Melrose, Grove and Oak townships. It is mostly flat, and from 25 to 40 feet above the river; but one to two miles south from Sauk Center, on the west side, it is partly in kame-like knolls and partly in massive swells, 15 to 40 feet above the hollows and 40 to 60 feet above the river. The plain of modified drift at Richmond and in the west part of Wakefield has a hight of about 30 feet. East of this the Sauk river is bordered by morainic till for a short distance about one mile west of Cold Spring, as also again through nearly three miles, beginning one and a half miles east of Cold Spring and extending to Rockville.

A very remarkable belt of modified drift reaches from the Sauk river at Cold Spring northeast and north to the Watab river in section 30, Saint Joseph, and continues thence northeasterly along this stream to the extensive plain of modified drift in the northeast quarter of Saint Joseph and the northern third of Saint Cloud. The village of Cold Spring is on valley drift about 20 feet above the river, and some portions of the alluvial bottoms bordering the river are only 5 or 10 feet above it, being subject to annual overflow. Next north and west of the village is a terrace of modified drift nearly three miles long and one-fourth to three-fourths of a mile wide, about 50 feet above the river, probably formed at the same date with the Richmond plain and the modified drift in Paynesville and westward along the southwest side of the North branch of Crow river. A mile north from Cold Spring there is a further ascent of 40 feet along an escarpment coinciding nearly with the south line of sections 10 and 11, Wakefield, to a plain which occupies the southeast part of section 10, about all of section 11, and the northwest part of section 12, elevated 90 feet above the river. This tract, consisting of sand and coarse gravel, often with a foot or two of clay next to the soil, reaches northeast through the south part of section 1, Wakefield, and section 6, Rockville, and thence north two miles, with a width varying from a sixth to a third of a mile, to the Watab river in the N. E. ¼ of section 30, Saint Joseph. Onward it has a width of about a half mile along the Watab river for three miles northeast to near Saint Joseph village, where it expands into the plain that stretches east to Saint Cloud. Between Cold Spring and Saint Joseph this modified drift, marking a former water-course, is bounded on each side by morainic till 40 to

60 feet higher. Its descent in these eight miles is about 75 feet, and the plain of similar modified drift between Saint Joseph and Saint Cloud, also eight miles, descends 50 feet, making the whole slope in sixteen miles approximately 125 feet, or an average of nearly eight feet per mile.

Elevations, Fergus Falls line Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Mississippi river bridge, grade	74.1	1033
Saint Cloud	74.5	1038
Sauk river, water, 1035; grade	78.0	1050
Saint Joseph	82.0	1088
Watab river, water, 1058; grade	82.6	1075
Collegeville	84.8	1094
Avon	90.1	1131
South branch of Two rivers, water, 1137; grade	94.4	1144
Albany	96.2	1201
Getchell creek, water, 1191; grade	101.1	1203
Freeport	102.4	1240
Sauk river, water, 1172; grade	106.1	1185
Melrose	108.4	1211
Sauk river, water, 1201; grade	110.7	1213
Summit, cutting 11 feet; grade	114.1	1276
Sauk river, water, 1212; grade	115.7	1236
Sauk Center	117.2	1254
Hazel creek, water, 1235; grade	117.7	1256
Ashley creek, water, 1276; grade	121.7	1288

The elevation of the Mississippi river along its course between this county and Benton and Sherburne counties is given in the preceding chapter.

The highest land in Stearns county is in its northwest part, where portions of Millwood, Melrose, Sauk Center, Ashley, Getty and Raymond are 1,350 to 1,400 feet above the sea-level. The tops of some of the morainic hills in Farming, northeastern Munson, and the southeast corner of Wakefield, are about 1,350 feet above the sea, being 150 to 250 feet above adjoining areas. The lowest land in the county is the shore of the Mississippi river at Clearwater, 938 feet above the sea.

Estimates of the average hights of the townships are as follows: Brockway, 1,125 feet; Le Sauk, 1,060; Saint Cloud, 1,060; Saint Augusta, 1,040; Lynden, 1,020; Fair Haven, 1,100; Saint Wendel, 1,120; Saint Joseph, 1,100; Rockville, 1,120; Maine Prairie, 1,140; Holding, 1,140; Avon, 1,150; Collegeville, 1,175; Wakefield, 1,160; Luxemburg, 1,180; Krain, 1,225; Albany, 1,210; Farming, 1,200; Munson, 1,175; Eden Lake, 1,180; Millwood, 1,275; Oak, 1,210; Saint Martin, 1,180; Zion, 1,210; Paynesville, 1,175; Melrose, 1,275; Grove, 1,240; Spring Hill, 1,240; Lake Henry, 1,260; Sauk Center, 1,280; Getty, 1,320; Lake George, 1,300; Crow River, 1,225; Ashley, 1,340; Raymond, 1,340; North Fork, 1,270; and Crow Lake, 1,240. The mean elevation of Stearns county, derived from these figures, is 1,195 feet above the sea.

Soil and timber. The black soil is generally one to two feet deep throughout this county. It is the surface of the glacial or modified drift enriched and blackened by the decay of vegetation during many centuries. The subsoil for the greater part is the pebbly and stony clay called till; but considerable tracts along the Mississippi, Clearwater and Sauk rivers, and southwest of the North branch of Crow river, as also the northeast part of Maine Prairie township and adjoining portions of Saint Augusta and Rockville, have a subsoil of gravel and sand. Wheat, oats, barley, rye, corn, sorghum, potatoes, other garden vegetables, live stock, and milk, butter and cheese, are the chief agricultural products. Nineteen-twentieths of this county are probably fitted for cultivation, the exceptions being frequent sloughs, which yield good hay, the bluffs along creeks and rivers, and roughly knolly or hilly and stony portions of the morainic belts, which are valuable for pasturage.

About a third of Stearns county is prairie, including most of the area west of Richmond and southwest of the Sauk river; also, tracts one to two miles wide along the northeast side of this river; the greater part of the plains of modified drift in Saint Joseph, Saint Cloud and Maine Prairie; Winnebago prairie on the Mississippi river in southeastern Brockway and northern Le Sauk; and limited areas of the modified drift in Saint Augusta, Lynden and Fair Haven. Most portions of the modified drift which are not prairie bear only a scanty growth of timber, in which black and bur oaks are the leading species. Fully half of the county was originally covered by large timber, the greater part of which still remains, though much wooded land has been cleared to make farms. Basswood, and species of oak, elm, maple, ash, birch and poplar, are the principal trees. A grove of white pines occurs on the bluff of the Mississippi river in Saint Cloud; and both white and jack pines grow on the plain of modified drift that borders this river in Brockway. Tamarack flourishes in swamps, and supplied the name of the Watab river, and thence of Watab township in Benton county, this being the name given by the Chippewas to the long threads obtained by splitting tamarack roots, used by them in sewing their birch canoes.

GEOLOGICAL STRUCTURE.

Outcrops of Archæan rocks, chiefly syenite, occur in Ashley, Sauk Center and Melrose in the northwest part of this county; and in Wakefield, Rockville, Saint Joseph, Saint Augusta, Saint Cloud, Le Sauk and Brockway in its eastern half. Cretaceous beds, containing thin seams of lignite, are exposed in the banks of the Sauk river near Richmond in Munson township, and at other localities a few miles from Richmond both to the north and south. Other portions of this county, and even the greater part of these townships, are covered by the glacial and modified drift, having no exposures of the underlying formations.

Archæan rocks.

Ashley. The most northwestern rock-outcrops of Stearns county are found in Ashley township, eight miles west of Sauk Center. They lie close south and southwest of a school-house at the south side of Ashley creek, partly in the S. W. ¼ of the N. W ¼ of section 17, owned by George H. Pendergast, and more in the S. E. ¼ of the N. E. ¼ of section 18, on land of Lucas Kells. This rock has numerous exposures, the largest being about a hundred feet long, upon an area which reaches thirty rods from east-southeast to west-northwest, their hight being from one to five feet above the general level. It resembles syenite, but contains much of a light-green mineral (probably epidote), like that found in the rocks outcropping thirty and forty-five miles farther north, in Todd and Cass counties. This takes the place of hornblende and mica, neither of which can be detected. Joints occur from one to five or ten feet apart. No schistose or laminated structure was observed. Vein-like masses of coarsely crystalline orthoclase, enclosing small amounts of white quartz and of the green mineral, occur in this rock at many places, often extending ten feet or more, and varying from one to several feet in width. These ledges may be quarried for coarse masonry.

Sauk Center. Exposures of rock are found at the southwest side of the railroad from an eighth to a fourth of a mile southeast from Sauk Center depot. They are partly upon the land of the railroad, but mostly for their western portion upon land owned by Tobias Carl. The largest outcrop is about fifty rods from the depot, and a hundred feet southwest of the railroad, covering an area about six rods long from northwest to southeast by two to three rods wide, and rising only one to two and a half feet above the general surface. This ledge has several distinct varieties of rock. The greater part is a reddish feldspathic gneiss, laminated from northeast to southwest, or a similar syenite where this lamination is absent. Masses a few feet in extent, not definitely separated from the foregoing, are very coarsely crystalline, flesh-colored feldspar and quartz; the latter constitutes about one-fourth part; and both occur in crystalline masses one to two inches long. Portions of this gneiss and syenite are porphyritic with feldspar crystals up to a half inch, or rarely an inch, in diameter.

The most southern part of this ledge, extending thirty feet from east to west, and ten feet wide, divided from the last by a width of about two rods which is covered with drift, is a very hard and compact, dark, granular rock, perhaps to be called syenite, in which the most abundant mineral is apparently hornblende. A small space of this, about eight feet long and four feet wide, shows a vertically laminated structure, curving from a south to a southeast course. Glacial striæ, clearly seen on the west part of this southern outcrop, bear S. 40° E.

Eight rods west from the last is another exposure of the same hard, dark rock, about two rods in extent, not rising above the general level. About fifteen rods west-northwest from the large outcrop first described, another of similar rock is found, being mainly gneiss, laminated from northeast to southwest. This ledge is about fifty feet long from west-northwest to east-southeast, and rises from one to one and a half feet above the general surface. Again, some twenty-five rods southeast from the first described exposure, excavations at each side of the railroad, five to fifteen feet below the track, show the dark, tough hornblendic rock, like its two exposures farther west, except that here it is more intersected by joints, which are from one to six feet apart. On the southwest side of the railroad this rock is uncovered for a length of a hundred feet; but on the northeast side only two or three small knobs are visible. None of the outcrops are suitable for quarrying.

Melrose. The next exposure of the bed-rock is eight miles east-northeast from the last, at Clark's mill, in Melrose. This mill, situated on the south side of Sauk river about ten rods west of the bridge, is founded on a ledge of very hard, coarse, red syenite, which also extends some twenty-five feet from the mill, half-way across the waste-way of the dam.

In the west part of Melrose village, a third or half of a mile west from this mill, and on the level plain of valley drift, rock has been encountered in attempts to dig wells at W. H. Rothaermel's house. Its depth below the surface is about six feet, and it has an extent of a hundred feet or more. A well blasted into this rock supplied the stone for the foundation of the Methodist church near by. It is a dark, unlaminated, rather coarsely crystalline hornblendic rock, different from any other found in this district.

Wakefield. Several outcrops of very hard, dark dioryte, and of coarse syenite occur within a radius of a fourth of a mile about the corner of sections 19, 20, 29 and 30, Wakefield. This is on the north side of the Sauk river, two miles east of Richmond, and about twenty miles southeast from Melrose. One of these knobs rises forty feet above the general level. The abutments of the Richmond bridge were quarried at this locality.

About one and a half miles farther east, near the centre of section 21, a small outcrop of coarse syenite occurs in and close south of the road, its length being four rods and its hight three or four feet. It is intersected by joints at intervals of two to six feet.

At Cold Spring, one and three-fourths miles farther east, a fine-grained, reddish, much-jointed syenite has abundant outcrops, underlying the mill and dam, and covering an area on both sides of the Sauk river equal to a quarter of a mile square, with its highest points 20 to 25 feet above the river. It has been somewhat quarried for local use in foundations, walls, etc.

Rockville. Four miles farther east, massive outcrops of coarse-grained, gray granite, containing black mica, which weathers to yellow, occur near Rockville. The most prominent mass of this rock is at the east side of Mill creek, a quarter of a mile south of Rockville mill, forming a knob forty or fifty rods in length and breadth, and fifty feet high. This rock is very free from joints or seams, being sometimes unbroken for thirty or forty feet. Otherwise it appears to be well adapted for quarrying, to supply stone for heavy masonry, as bridge piers and abutments. Two other exposures of this rock are found a quarter of a mile northeast from this mill. The most southerly of these, situated east of the road, covers some thirty rods square, and rises about forty feet above the river; and the second, less than an eighth of a mile farther north, crossed by the road and lying mostly between the road and the river, covers an area 30 by 20 rods in extent, and rises 20 to 30 feet above the river. Both consist of massive, rounded ledges, with few seams or joints, which are often twenty to thirty feet apart.

Saint Joseph. In the N. E. ¼ of section 26 of this township, nearly four miles northeast from Rockville, massive, coarse-grained, gray syenite or granite, closely like that of Rockville, is exposed on the land of Fred Schilplin, about an eighth of a mile southeast from his house. It forms a rounded outcrop some twenty rods broad, rising ten feet above the general level, its hight above the Sauk river, three-fourths of a mile to the northwest, being about 35 feet. This ledge has few joints, one space fifty feet square being without a seam.

One and a half miles west-southwest from the last, an exposure of rock is reported in section 27, on land of I. S. Staples, at the east side of Sauk river, above which it is said to rise five to ten feet, covering an acre or more.

Saint Augusta. Granite, containing flesh-colored feldspar and black mica, is exposed near the middle of section 19, Saint Augusta, about a fourth of a mile west of Luxemburg post-office and St. Wendel's church. This is four miles east-southeast from Rockville and eight miles south-southwest from Saint Cloud. It lies on the west side of a slough, above which it rises 15 to 20 feet, its extent being about twenty rods. It is divided by joints three to fifteen feet apart; the course of their principal system, nearly vertical, is from northwest to southeast.

Saint Cloud. This township has many exposures of these rocks, principally syenite.

In the N. E. ¼ of section 32 a reddish gray syenite or granite, and in the N. W. ¼ of section 33 a very dark syenite, containing a large proportion of hornblende, form quite extensive outcrops, in each case covering an area equal to a quarter of a mile square. An eighth of a mile west of the road, these rounded hillocks of rock rise 20 to 25 feet above the general level; and close east of the road and for an eighth of a mile or more from it, their hight is five to ten feet. About forty rods farther north, the road goes by ledges of syenite nearly like that of the quarry at Sauk Rapids. These are probably in the southeast corner of section 29; they lie close west of the road, above which they rise 15 to 20 feet. The next two miles to the north and northwest have abundant outcrops of gray and reddish syenite, of which the following is a list in part.

On land of Jacob Streitz, in the N. W. ¼ of the N. E. ¼ of section 28, considerable quarrying has been done, forty cords or more of the stone having been sold for masonry in Saint Paul. This is an excellent gray syenite, rising about ten feet above the general surface, well adapted for supplying dimension stone. It is near the eastern side of this tract of abundant ledges; and the hills one to one and a half miles east and northeast, rising 50 to 75 feet higher and 125 to 150 feet above the Mississippi river, are morainic drift.

A quarter of a mile west of the last, on land of Louis Hohmann, in the N. ½ of the N. W. ¼ of section 28, ledges of the same rock as the last cover two or three acres, rising about five feet above the general level of the surrounding modified drift. Some quarrying has also been done here.

On land of Ferdinand Hartmann, in the north edge of the N. E. ¼ of section 29, he has quarried during several years, in two low outcrops of syenite, selling the stone for $8 per cord at Saint Cloud. The southwestern outcrop, six rods square, is a somewhat coarse-grained, reddish syenite, divided by joints from one to eight feet apart. The other ledge, fifteen rods north-northeast from the last, is about ten rods long from west to east by six rods wide. This is mainly red syenite like the former, but includes a large mass, occupying an area about four rods square, of finer-grained, bright gray syenite, containing occasional scales of black mica. At its border a gradual change of color takes place from the gray to the red.

An area of several acres of reddish syenite, like that of the last localities, begins thirty or forty rods northwesterly from the last, and reaches a sixth of a mile or more northward. This is on land of Matthias Leim, in the S. ½ of the S. W. ¼ of section 20, and of Nicholas Scheuer in the north half of the same quarter-section. It rises in rounded hills and knolls 30 to 50 feet above the lowland eastward.

About forty rods northwest from the last, in the N. W. ¼ of the S. W. ¼ of this section 20, owned by Nicholas Scheuer, gray syenite, closely like that of Streitz and Hohmann, and of Hartmann's northern quarry, forms a hill which covers six or eight acres and rises 50 feet above the general surface. It is smoothly glaciated, but retains no clear striæ. This rock has few joints, sometimes none for an extent of thirty feet. Here and upon many of the ledges of this region a scale of rock, a fourth to a half of an inch thick, has become separated, or is easily separable from the surface by weathering. In some places this might be attributed to forest or prairie fires, which seem often to have produced such scaling; but here it is notably exhibited on bare ledges six rods or more in extent.

Within a mile westerly are many lower outcrops of this syenite, rising 10 to 20 feet above the average of the vicinity. Good locations for quarrying are reported on the land of William Besinius, on the S. E. ¼ of section 19, and of Jacob Hiltimes in the west half of this section.

The red syenite continues from the ledges owned by Hartmann and Leim northerly to the land of the Saint Cloud Granite Manufacturing Co., L. A. Evans, agent. This is the N. W. ¼ of the S. W. ¼ of section 17, where excellent quarrying stone is found. A few years ago a block of this red syenite was obtained for a monument pedestal, which had been sought but could not be supplied (so reported) from the famous quarries of similar stone at Aberdeen, Scotland. The size of this block was 7 feet square by 2½ feet high, its weight being ten tons. It was cut and polished in Saint Cloud, and was sold in Chicago for about $800. This quarry has not been worked for the past two or three years.

Excellent localities for quarrying the same red syenite also occur within a half mile west and southwest from the last, in the S. E. ¼ of section 18, owned by H. C. Waite, and in the N. W. ¼ of section 19. Some of these localities also yield gray syenite and that which is gray, tinted reddish.

Syenite outcrops in the N. W. ¼ of section 17, at the northwest side of the road about a half mile west of John Becker's. Its extent is about fifteen by ten rods, and its hight is some twenty feet above the adjoining lowland and river, an eighth of a mile west, and eight feet above the road. This ledge exhibits some marks of water-wearing. A system of nearly vertical joints crosses it from north to south, varying from six inches to four feet apart; and others, less conspicuous and less numerous, extend from east to west.

The only exposure of rock beside the Mississippi river in this county below the Saint Cloud bridge, is about a half mile south of the state normal school, at C. Bridgeman's steam saw-mill and for twenty rods to the south.

It is coarse gray syenite, with joints ten to twenty feet apart, and forms small ledges five to ten feet above the river.

Fifteen to twenty rods south from the west end of the Sauk Rapids bridge, is a ledge of porphyritic, gray syenite, consisting mostly of feldspar, with about a fourth part of quartz, and including some hornblende and rare grains of mica. It rises some five feet above the river, and is traversed by nearly vertical joints one to eight feet apart. It has been slightly quarried.

Le Sauk. In this township, situated next north of Saint Cloud, these crystalline rocks are exposed upon the lowest mile of Watab river, and at several places within three miles thence north-northwest. The grist-mill and its dam, owned by J. B. Sartell & Sons, on the Watab river about a third of a mile above its mouth, are founded on gray syenite. This is exposed to view only on the south side of the river, under the foundation of the north side of the mill, rising a few feet above the water of the flume below the dam. It was quarried for this mill, and is a desirable building stone.

Mr. Sartell owns another quarry a half mile northwest from this mill, covering several acres and rising twenty feet above the general level. It is in or near the S. E. ¼ of section 17. This has a more reddish tint. Quarrying has been done here more or less during the past ten years, perhaps yielding quarried stone to the value of $1,000 in all, only for use in this vicinity.

A third of a mile east of the last, in the south part of section 16, is another outcrop of rock, similar to that at the grist mill. This covers about two acres. It has a low smoothed surface, not much above the general level.

Another ledge of similar syenite or granite is seen at the west side of the road, east of the north part of Clark lake, in the south half of section 8. This also covers ten acres or more, its hight being about ten feet.

On or near the east line of section 9, a rock-outcrop, said to be coarse-grained and of iron-rusty color, covers several acres and rises some fifty feet above the Mississippi river, which is ten or twenty rods farther east.

Reddish fine-grained syenite has been somewhat quarried for local use, in or near the N. E. ¼ of the N. E ¼ of section 7, on land of D. B. Searle. Farther northwest, near the centre of section 6, similar rock has outcrops at many places along a distance of about half a mile from east to west, not extending into Saint Wendel township.

Brockway. A medium-grained, gray granite or syenite, containing garnets a fourth of an inch in diameter, is exposed on the N. W. ¼ of section 33, in the southeast part of Brockway, on land of William Gordon, about a quarter of a mile west from the road and from his house. It shows only a smooth flat surface, ten by fifteen feet in extent, not rising above the general level.

Rock is also reported to occur in the west shore of the Mississippi river, about fifteen rods south from the northeast corner of this section 33. The rock is exposed also in the east bank and in the channel of the river, but its outcrops rise only two or three feet above extreme low water. This is about a mile north of the high hills of rock at the east side of the river in Watab.

Cretaceous beds.

Before the ice age Cretaceous strata probably covered the western two-thirds of Minnesota,* and on this area the greater part of the material of the drift is derived from these beds. The remnants of them that escaped the glacial erosion are now nearly everywhere concealed by the drift. In Stearns county their only exposures are found in the neighborhood of Richmond.

Mr. Eames† observed the following section, horizontally stratified, near this village, in the banks of the Sauk river:

Sand and gravel [modified drift]	40 feet.
Blue clay with crystals of selenite	4 feet.
Impure coal [lignitic clay, including three inches of lignite]	2½ feet.
Bituminous limestone, forming the bed of the river -	10 feet.

This was doubtless at the locality of the drift and shafts mentioned beyond; and the report of limestone in place is an error. About half a mile below this exposure, Eames reports a ferruginous sandstone or conglomerate four feet thick, seen in the bank of the river along a distance of twelve yards.

Three miles north of Richmond, in the S. E. ¼ of the N. E. ¼ of section 2, Munson, north of the range of morainic hills, a section noted by Eames in a ditch dug for drainage consisted of yellow and blue clay with three seams of lignite from one to six inches thick. The stratification here was irregularly confused and in part vertical, apparently on account of slides. Three shafts were dug near this place in the hope of discovering workable lignite, by Mr. Theodore Bock. One of these went twenty-five feet, finding a lignitic layer

* As shown by Prof. Winchell in the *Bulletin of the Minnesota Academy of Natural Sciences*, vol. i, pp. 347–9.

† *Geological Reconnoissance of the northern, middle, and other counties of Minnesota*: 1866.

six inches thick at thirteen feet, enclosed in blue clay, which, by boring twenty-five feet below the bottom of the shaft, was found to reach a depth of fifty feet, containing pyrite in some portions but no other lignitic seam. The other two shafts, forty and thirty feet deep, were wholly in drift. Eames referred this "coal" to the Cretaceous age, and rightly discouraged further mining for it, stating that his survey of the lignite-bearing strata on the Sauk and Cottonwood rivers "has demonstrated the fact that the state contains no outcrop of coal of value, in so far as the counties examined and points coming under observation are concerned."

Repeated fruitless observations for lignite have been made, however, by shafts in the Cretaceous beds on the southwest side of the Sauk river in the N. W. ¼ of section 23, Munson, a fourth to a half of a mile west of Richmond. In 1871, at a point some thirty rods west of the bridge and less than a hundred feet from the river, a shaft was dug and bored to the depth of 120 feet. Its top is about 25 feet above the river. Black clay or shale with some lignite, which is seen here in the river's bank, was penetrated and found to be three feet thick. A drift dug in 1865, starting about twenty-five feet farther northwest and following the lignitic layer sixty feet, found it to dip westward about four feet in this distance. It was said to contain "a seam of lignite four inches thick, which kept increasing in thickness, but remained impure and was considerably mixed with shale." Above and below the lignitic stratum is bluish gray clay or shale containing rarely crystals of selenite (gypsum) up to three inches long. Mr. J. H Kloos* found in the material brought up from the shaft "several fragments of shale containing scales of cycloid fishes, which had been met with near the surface." At a depth of 112 feet, according to Kloos, this boring reached "a hard rock, which proved to be granite. It was drilled for eight feet, and the fragments brought to light by the pump consist of feldspar, quartz and pyrites, such as are found in varieties of pegmatite or graphic granite, which I also found at the nearest outcropping ridges of the crystalline rocks." Nearly a quarter of a mile west from this place and about 75 feet above the river, another shaft was dug and bored in 1871 to the depth of 180 feet. This passed through a considerable thickness of drift, below which were blue, white and yellowish plastic clays, and shale. No more lignite was encountered than in the drift and the other shaft.

* "A Cretaceous basin in the Sauk valley, Minnesota," *Amer. Jour. of Science* (3), iii, 17-26; 1872.

Again, in 1880 and 1881, the Richmond mining company claim to have bored to the depth of 125 feet at a point only ten feet distant from the shaft and boring first described, close to the river. The only lignite found is the layer seen above the river-level; blue clay, with thin laminæ of white and yellow clay, lies above the lignite; and bluish or greenish gray clay and shale extend below to the bottom of this section. No sand nor gravel, nor any hard rock, was encountered. In respect to these explorations, it must be added that it seems certain that no valuable deposits of lignite exist in this region, nor indeed in any portion of this state.

The only fossils known to have been found in these shafts are the fish-scales before mentioned. A shark's tooth was also found by Mr. Kloos in the plastic clay that here forms the bank of the Sauk river. Two miles south of Richmond, H. Sieverding's well, situated at a hight of 30 feet above the Sauk river, among very irregu'ar morainic hillocks and low ridges, in the S. W. ¼ of section 35, Munson, dug in 1871 and visited by Mr. Kloos, is reported by him as follows: "At a depth of eight feet the blue clay was struck, passing into shale . . and containing a number of fossils. The water of this well was strongly saturated with sulphureted hydrogen, but lost the taste and smell almost entirely after having been exposed for some time to the atmosphere. When at the place, I was not able to obtain more than fragments of the shells, which I had, however, no difficulty in recognizing as belonging to the genus *Inoceramus.* Afterwards the well was dug down further, and I obtained some pretty fair casts and parts of the shells. . . . . When last heard from, the well had a depth of 55 feet, and a boring had been sunk to a further depth of 25 feet. The following section is a nearly accurate description of the strata traversed:

8 feet gravel and sand.
30 " dark blue laminated clay. Fragments of *Inoceramus problematicus* and crystals of gypsum.
8 " clay and hard sandy shale of a light blue color, with pyrites, mica, and fish scales. Cast of *Inoceramus.* At 40 feet a thin seam of lignite.
10 " same clay with more shale 3 to 4 inches thick. Shells of *Inoceramus* and *Scaphites* in the shale having retained their original color and pearly luster. In 50 feet another seam of lignite.
15 " dark blue clay without shale; color darker than the clay above and turning almost black. At 65 feet a hard shale of a grayish black color had to be drilled through.
10 " clay with thin layers and seams of pyrites."

Mr. F. B. Meek, to whom these fossils were submitted, wrote Mr. Kloos as follows: "The specimens . . . . consist of *Inoceramus problematicus*, impressions apparently of *Ammonites percarinatus*, scales of fishes and a small shark tooth allied to *Corax* or *Galeus* Among the drawings also sent by you, there is one of the inner volutions of *Scaphites larviformis*, or some nearly allied form. From these fossils, and the lithological character of the bed in which they were found, there can be no reasonable doubt, that it belongs to the Cretaceous system, as well as to the Benton group of the Cretaceous series as developed in the upper Missouri country. As you have suggested, the locality at which these specimens were collected, cannot be far from the eastern limits of the great Cretaceous basin that occupies so much of the country along the upper Missouri; and it is very desirable that the eastern boundary of this group of rocks should be traced out as accurately as possible, through Minnesota. Owing to the heavy deposits of drift there, however, this will be a difficult task, and can only be done by careful observations of all that is revealed by deep wells and other excavations. Consequently it is important that all the facts brought to light in this way should be carefully noted and published."

Glacial and modified drift.

Glacial striæ observed at Sauk Center, as before mentioned, bear S. 40° E., referred to the true meridian, being at right angles with the striæ noted in

Sauk Rapids, Benton county, about forty miles farther east. Nearly all the ledges of Stearns county are planed and worn to a smooth surface by the ice-sheet; but, excepting at Sauk Center, none of them, so far as seen in this survey, retain glacial striæ, because of the slight disintegration wrought upon their surface by rains and frost.

The contour and material of the drift deposits have been stated in an earlier part of this chapter. The stages in the recession of the ice-sheet which they indicate are somewhat complex. During the culmination of the last glacial epoch, an ice-current from lake Superior and northern Wisconsin extended over the east half of this county, to a limit in Luxemburg, Wakefield, northeastern Munson, Farming, Albany, Krain, and northeastern Millwood. In these townships, extending from south-southeast, to north-northwest, the ice-current from the northeast, by which the striæ in Sauk Rapids were made, was confluent with the ice-current from the northwest, which striated the rock at Sauk Center. West of this line of confluence boulders and gravel of limestone abound, derived, like the limestone everywhere present in the drift of western Minnesota and of Dakota, from the limestone strata which have their nearest outcrops in the vicinity of Winnipeg, Manitoba. Fragments of lignite, and very rarely of petrified wood, are also found in this western drift. The drift brought by the ice-current from the northeast is distinguished by the absence of limestone and the presence of boulders and pebbles of igneous and sedimentary rocks peculiar to the region of lake Superior. A difference in color is also observable, the drift from the northwest and west being dark bluish gray, excepting near the surface, where it is weathered to a yellowish color; while the drift from the northeast has a lighter gray color and is more or less tinted with red. These colors are due to the condition of the iron present, which in its protoxide combinations imparts a bluish hue, in the condition of limonite yellow, and as hematite red. It exists under the first of these conditions in the Cretaceous clays and shales which have contributed probably more than half of the material of the western drift; and as hematite it colors the red shales and sandstones about lake Superior and the drift derived from them. The northeastern drift in Stearns county, however, does not usually show the reddish tint conspicuously, because it has become mingled with much material from other rock-formations in its long transportation. The morainic hills one to six miles west and northwest from Cold Spring consist of this northeastern drift, and the same forms the surface thence northeast to Saint Cloud and Le Sauk and onward all the way to lake Superior.

Remarkable changes took place in the currents of the ice-sheet during its departure. The ice from the northwest and west, becoming relatively thicker, pushed back that from the northeast upon a large area reaching from the southeast part of this county east-northeastward to the Snake and St. Croix rivers, even advancing into the edge of Wisconsin, as has been shown in the chapter on Chisago, Isanti and Anoka counties. After this western ice-lobe began to retreat, the line at which it first halted or perhaps re-advanced, is marked by the morainic accumulations described in the two preceding chapters and referred to the time of the fifth or Elysian moraine. The continuation of this morainic series in Stearns county forms the belt of knolly and hilly till east, south and west of the plain of modified drift in Maine Prairie. The angle made in the glacial boundary by the confluence of the western and eastern ice-fields was probably at or near the southeast corner of Wakefield, where the most prominent morainic hills in this county are found. On the south margin of the northeastern ice at this time was apparently accumulated the hilly till of Rockville, of the south half of Saint Joseph, excepting in sections 31, 30 and 19, and of the southeast part of Saint Cloud, the continuance of this series being through northern Haven and Palmer in Sherburne county. The gravel and sand forming the plain of Maine Prairie were deposited by the waters that had flowed down from the slopes of the adjacent ice-fields, which converged toward this area.

By the next retreat of the waning ice-sheet its boundary was carried back to the sixth or Waconia moraine, which is represented in southern Stearns county by the drift hills and knolls on the east and north border of Luxemburg, along the line of Eden Lake and Munson, and thence southwest through Paynesville to Cape, Bad Luck in Roseville, Kandiyohi county, accumulated along the north margin of the western ice-lobe. The south line of the ice moving from the northeast and north seems to have extended at this time along the northwest side of the Watab river in Saint Wendel and Saint Joseph, and thence westward through Collegeville, Farming, Saint Martin and Spring Hill, Grove, Getty and Raymond. When the recession from the Elysian moraine began, the outlet of drainage from the confluent ice-fields appears to have been from Cold Spring northeast to the Watab river and Saint Joseph, along the valley occupied by modified drift which has been before described. The scarcity of limestone in the gravel along this old water-course indicates that the glacial melting was then progressing most rapidly on its north side. At the somewhat later date of the Waconia moraine, the angle of confluence of the ice from the west and northwest with that from the northeast and north seems to have been at Glenwood in Pope. county. The glacial floods which there poured down from the converging ice-slopes and thence flowed southeast along the present course of the North branch of the Crow river to Paynesville and then east-northeast to the Sauk valley at Richmond, eroded a broad channel into the till of southwestern Stearns county. The northeast limit of this erosion is the bluff of till 40 to 100 feet high, which rises close on the northeast side of this river from North Fork to Paynesville, a distance of twenty miles. From these floods were deposited the extensive beds of modified drift which reach from eastern Pope county through the southwest part of Stearns and the northeast of Kandiyohi county to Paynesville and Richmond.

When the ice-sheet again retreated, to the line of the seventh or Dovre moraine, its western lobe was withdrawn from this county, but the ice-fields flowing from the north appear to have extended to the moraine in Brockway, the northwest part of Saint Wendel, Avon, northeastern Albany, Krain, northern Millwood and Melrose, and the northeast corner of Sauk Center. At this time, also, the modified drift along the upper part of the Sauk river and on the Mississippi in Le Sauk and Brockway was deposited.

Boulders are frequent or often abundant in the morainic accumulations of till; but in the smooth, undulating deposits of till they are usually so few that they give no trouble in the cultivation of the land. Numerous pieces of sandstone, up to one or two feet in size, like that outcropping at Hinckley in Pine county, were noticed in Le Sauk and in Sauk Rapids on the opposite side of the Mississippi.

Wells in Stearns county.

Brockway. Wells on the plain of modified drift bordering the Mississippi river are 30 to 50 feet deep, wholly in sand and gravel. In the till of the central and west portions of the township wells vary from 15 to 75 feet in depth.

Le Sauk. E. G. Mathews; sec. 21: well, 20 feet; soil, 2; sand, 7; yellow till, picked, 9; quicksand, with water, 2 feet.

A. G. Hart; sec. 28: well, 27 feet; soil, 2; yellow till, picked, 6; sand, with water, 3; and again yellow till, with some portions darker, much harder than the upper till, 16 feet; no water was found in the lower till.

Saint Cloud. Wells in the town are mostly 15 to 25 feet deep, being in sand and gravel; but on the street next to the river wells go 60 to 75 feet, passing through till, only thinly overlain by sand.

Christian Stanger; sec. 18: well, 14 feet; soil, 2; all sand and gravel below.

Saint Augusta. H. Beumer & Co.; at the post-office, in the S. W. ¼ of sec. 12: wells, 10 to 15 feet deep, all caving gravel and sand.

Saint Joseph. J. H. Linnemann; in the village: well, 25 feet; soil, 1½; all below is sand and gravel, with pebbles up to three or four inches in diameter.

Frederick Schrœder; N. E. ¼ of sec. 20: well, 20 feet; soil, 1; yellow gravelly clay, too hard to be spaded, 1½; gravel, with pebbles up to six inches in diameter, 3; fine gravel and sand, with water in coarse sand at the bottom, 15 feet, and continuing below. The water of this well is hard; but in a thousand or more boulders and cobbles gathered here for cellar-walls, etc., not one of limestone is found, and limestone pebbles are very rare, scarcely one in two hundred, in the gravel of Mr. Schrœder's well and cistern. Wells in till in this township go 15 to 60 feet; if the surface water fails to yield a sufficient supply, lower water-veins are found only at considerable depths.

Maine Prairie. A. Meservey; N. W. ¼ of sec. 9: well, 22 feet; soil, 2; yellow clay, 3; and gravel and sand, to water, 17. Other wells in this neighborhood are 20 to 30 feet deep, mostly in gravel and sand.

In the village wells go 15 to 30 or 40 feet, increasing in depth toward the northeast. The deepest is Mr. Alexander Spalding's, 40 feet; soil, 2; with sand and gravel for all below, the coarsest layers containing pebbles up to six or eight inches in diameter.

Holding. R. Holding, at Holding's Ford: well, 15 feet; soil, 1; gravelly and clayey "hardpan," 3; fine gravel and sand, 11 feet, becoming quicksand at the bottom; water is plentiful and good, hard. This is on a narrow belt of modified drift, a third of a mile wide, bordering the South branch of Two rivers.

Wakefield. At St. Jacob's church in the north part of sec. 12, wells are 40 feet deep, all sand and gravel, containing pebbles up to six or even twelve inches in diameter. John Danzel's well, in the S. E. ¼ of sec. 2, a half mile farther northwest, is 36 feet deep, all the way in till.

Wells at Cold Spring are about 20 feet deep, in gravel and sand.

Luxemburg. John Jungels; sec. 1: well, 34 feet; soil, 2; yellow till, picked, 10; gravel, 15; blue till, harder than the upper till, 7; water rose quickly seven feet from gravel and sand at the bottom.

John Allenbecker; a fourth of a mile south from the last, in the same section: well also 34 feet deep; soil, 2; yellow till, 2 to 10 feet; bounded below by a plane dipping steeply to the north; and sand and gravel thence to the bottom.

Krain. William McGregor; sec. 8: well, 24 feet; soil, 1; yellow till, picked, 22, its last foot reddish; gravel, 1 foot and continuing deeper, with water which rose eight feet in a half hour. About a fourth part of the gravel intermixed in this till is limestone.

Munson. William Schulte; N. ½ of the S. E. ¼ of sec. 2: well, 24 feet; soil, 1; yellow till, partly picked, 21; and sand, 2 feet, with soft water.

At Richmond wells are 16 to 20 feet deep, wholly in fine gravel and sand.

Eden Lake. John P. Meyer; N. E. ¼ of sec. 4: well, 47 feet; soil, 2; yellow till, 6; sand and fine gravel, 39, to water. Another well here, 38 feet deep, was soil, 2; yellow till, 7; sand and fine gravel, 25; very hard clay, not gravelly, 8 inches; sand as above, 3 feet; and blue till, very hard, dug into only one foot.

D. J. Hanscom; sec. 24: well, 31 feet; soil, 2; yellow till, picked, 10; and stratified sand and fine gravel, some of its layers quite hard, 19 feet, to water, which is two or three feet deep. These three wells and the two in Luxemburg, six miles farther east, indicate a recession of the ice, attended with deposition of modified drift, followed by a re-advance of the ice at the time of the formation of the sixth or Waconia moraine. Some of the wells in Eden Lake, however, are wholly in till, one such in sec. 10 being 70 feet deep, finding the till yellowish to 30 feet and gray below, all hard, mostly picked.

Millwood. John Ahearn; S. E. ¼ of sec. 12: well, 32 feet; soil, 1; yellow till, spaded, 6; much harder blue till, picked, 22; gravel and sand, with water, 3 feet, and extending lower. Wells throughout this township are from 10 to 35 feet deep, in till.

Oak. Joseph Hoeschen; Freeport, in the S. W. ¼ of sec. 2: well, 33 feet; soil, 1; yellow till, spaded, 7; sand and fine gravel, 25 feet, with water at the bottom. Frank Benolken's well, near the village, in the same quarter-section, 35 feet deep, was soil, 1; yellow till, spaded, 10; blue till, 22; and sand and gravel, 2 feet and continuing deeper; water rose five feet in two hours. Wells in this region are mostly till to the bottom, 15 to 40 feet deep; water, obtained in seams of gravel and sand, often rises several feet.

Anton T. Vogt; New Munich, S. E. ¼ of sec. 18: well, 34 feet, all fine gravel and sand; two feet of water. Other wells here are mostly 15 to 25 feet deep in the same modified drift.

Saint Martin. Henry Loosbroek; near St. Martin's church, S. E. ¼ of sec. 35: well, 32 feet; soil, 1; yellow till, picked, 31; water comes plentifully from a layer of sand at the bottom.

Zion. Peter Weyer; N. E. ¼ of sec. 12: well, 15 feet; soil, 2; yellow till, all picked, 9; sand, 4; water two feet deep.

Michael Traun; S. E. ¼ of sec. 13: well, 64 feet; soil, 2; yellowish till, 49; and gravel, 13 feet, continuing deeper with no water; well abandoned. Ferdinand Grützmacher's well, in the S. W. ¼ of this section, about a half mile west from the last, is 63 feet deep, being soil, 2; yellow till, spaded, 10; darker and bluish till, less gravelly, also spaded, 38; and gravel, 13 feet, with water in its lower portion. Gas was encountered in both these wells, and by it a man was suffocated in a well a few rods west of Mr. Traun's, at the depth of about 50 feet.

M. F. Plantikow; sec. 32: well, 60 feet; soil, 2; yellow till, 10; blue till, very hard, picked, 48; water rose from the bottom twenty feet in one or two days.

Paynesville. Wells in the village are 15 to 20 feet deep, all gravel and sand, becoming quicksand at the bottom.

Melrose. In the village the section found below the soil is sand and gravel, 12 to 18 feet; then a bed 1 to 2 feet thick of very coarse gravel, containing rounded stones up to one foot in diameter, with abundance of water; underlain by very hard till, which is sometimes yellowish but in other places bluish gray.

Grove. Henry Imdeike; sec. 17: well, 20 feet; all yellow till; water seeps in plentiful amount. Wells in this township are all till, mostly 15 to 25 feet deep; but one was learned of, near its centre, 75 feet deep.

Spring Hill. Zeno Och; sec. 15: well, 22 feet; soil, 1; yellow till, spaded, but very hard, 18; gravel, 3 feet and extending deeper, with water.

Nicholaus Heunen; S. E. ¼ of sec. 22; well, 54 feet; soil, 1; yellow till, picked, 18; sand and gravel, stratified, with gravel predominating near the bottom and containing water, 35 feet. Other wells, 50 to 65 feet deep, are wholly or chiefly till, which becomes dark bluish and harder at the depth of 20 or 30 feet. Small pieces of lignite are often found in this till; and in one instance it contained a piece of wood two feet long, apparently a fragment of a small trunk or limb.

Lake Henry. Nicholas Longen; sec. 1: well, 35 feet; soil, 1; yellow till, 9 feet, very hard in its lower part; blue till, less gravelly, 25; water, disagreeable to smell and taste, comes in a gravelly vein at the bottom; except in very dry seasons this well is filled nearly to the top with surface water.

Sauk Center. Michael H. Lynch; sec. 1: well, 16 feet; soil, 1; yellow till, partly picked, 11; gravel and sand, 4, to water in quicksand.

William VanValkenburg; S. W. ¼ of sec. 1: well, 15 feet; soil, 1; yellow till, all picked, 11; sand and gravel, 3 feet and extending deeper, with water. A quite level tract surrounding this place within a radius of a half mile or one mile has the same order of drift deposits, and wells in at least a half dozen cases have the same depth as the two preceding, going two or three feet into modified drift of undetermined thickness below the till.

Wells in the town vary from 20 to 40 feet in depth, being mostly sand and gravel for their whole depth; but along Main street, as far north as to the Sauk Center House, this modified drift is found to be underlain by rock at 25 to 30 feet below the surface, similar to the rock-outcrops before described, southeast of the depot.

S. Simonton's well, on the corner of Third and Ninth streets, in the west part of this town, is 38 feet deep; soil, 1; sand aud gravel, containing pebbles up to three or four inches in diameter, 29 feet; and blue till, picked, 8 feet, containing at 32 feet a stick apparently of arbor vitæ or tamarack, four inches in diameter, lying horizontally across the well and requiring to be chopped off at each side. R. J. Marvin's well in sec. 29 of this township found numerous pieces of wood up to three or four inches long and one about a foot long, in hard and compact blue till 50 to 60 feet below the surface. These grew in preglacial or interglacial forests, which were overwhelmed by the ice-sheet, becoming a part of its drift.

Getty. Abner J. Lamb; sec. 11: well, 25 feet; soil, 1; yellow till, spaded, 21; blue till, picked, 2; and sand and gravel, 1 foot, underlain by till; water rose five feet in a few hours.

Gilbert Gilbertson; sec. 19: well, 46 feet; soil, 2; yellow till, spaded, 25; harder blue till, all picked, 19; water seeping from the lower part of the till filled the well to the depth of ninefeet in one day, and remains at this hight permanently. Shallow wells in this township sometimes find water of bitterish and unpleasant taste, but deeper wells obtain good water, all being in till.

Crow River. Wells throughout this township, excepting the upland of till in its northeast corner, are 12 to 25 feet deep in caving sand and gravel, containing pebbles and rounded stones up to six inches, or often eight to twelve inches, in diameter.

Ashley. A. M. Stiles; N. W. ¼ of sec. 11: well, 28 feet; soil, 2; a whitish, marly layer, 6 inches; yellow till, picked, 8½ feet; softer and less gravelly blue till, 17; water rose fifteen feet in one day from gravel at the bottom. The wells of this township are 15 to 35 feet deep in till, excepting near Ashley creek, where they are about 20 feet deep in sand.

North Fork. Michael M. Nugent; southwest corner of sec. 7, close south of Grove Lake academy: well, 45 feet; soil, 2; yellow till, soft to bore, 14; sand and gravel, containing water, 6; and blue till, 23, mostly soft, but very hard in the last two or three feet bored; water twenty feet deep, of good quality.

Wells in the south part of this township are 10 to 20 feet deep, wholly in caving gravel and sand.

Crow Lake. The wells throughout this township are also modified drift, being in their depth and material the same as in the south part of North Fork and in Crow River. They are mostly curbed with pine, but no contamination of the water by the decay of the curbing is noticed; though this often makes the water of wells in stratified clay, or in till entirely unfit for use.

MATERIAL RESOURCES.

The agricultural capabilities of this county, and its good supply of timber have been already noticed; also, the occurrence of thin seams of lignite in the Cretaceous strata near Richmond, and the futile explorations for it in workable quantity.

Water-powers have been utilized as follows:

Ward Brothers' saw- and grist-mill on the South branch of Two rivers at Holding's Ford; head, eight feet, flowing back nearly two miles.

M. Ebnet's saw-mill, in the south part of section 25, Krain, on a tributary of Two River lake; head, about fifteen feet.

William Ross' saw-mill on Spunk brook in the S. E. ¼ of section 5, Brockway; head about six feet.

J. B. Sartell & Son's grist-mill on Watab river in section 21, Le Sauk, having fifteen feet head; and their saw-mill in the same section, a quarter of a mile farther east on this stream near its mouth, having fourteen feet head.

Saint Joseph flouring mill, having eighteen feet head, and saw-mill, having fourteen feet head, on the South branch of Watab river a quarter of a mile west of Saint Joseph village, both owned by Ferdinand Danzel.

The Mississippi river at Sauk Rapids falls twenty-two feet in about a mile.

Sauk City flouring mill, owned by F. Arnold; on the Sauk river close to its mouth, in the southeast corner of Le Sauk; head, eight feet; canal thirty rods long.

Union flouring mill, J. E. Hayward; on the Sauk river a mile west from the last, in the north edge of Saint Cloud; head, ten feet.

Rockville flouring mill, O. Tenney; on Mill creek at Rockville, close to its junction with the Sauk river; head, fourteen feet.

Cold Spring flouring mill, H. C. Waite; on the Sauk river at Cold Spring; head, eight feet; seven run of stone and three crushers.

Hiltner & Proneth's flouring mill in the west edge of section 31, Oak; head, about twelve feet; canal a third of a mile long; three run of stone.

Melrose flouring mill, Edwin Clark; on the Sauk river at Melrose; head, eleven to thirteen feet; five run of stone for flour, and one for feed. The mill-pond is a mile long, covering 150 acres.

Sauk Center flouring mill, T. C. McClure; on the Sauk river at Sauk Center; head, ten feet; six run of stone. This dam raises the Little and Big Sauk lakes above their natural level, the latter being four miles long and a half to two-thirds of a mile wide, mostly in Todd county.

Neenah flouring mill, H. Beumer & Co.; on St. Augusta creek in the N. W. ¼ of section 13, Saint Augusta; head, fourteen feet; three run of stone for flour, and one for feed. There were mills formerly on this creek near its mouth and in the S. W. ¼ of section 27, Saint Augusta.

On the Clearwater river, at Clearwater, are three powers, as follows:

Thomas Tollington's saw-mill and furniture manufactory; ten or fifteen rods above the mouth of the river; head, five feet; can only be used when the Mississippi is at its low-water stage.

Clearwater flouring mills, C. F. Davis & Co.; a short distance above the last; head, fifteen feet.

Upper dam of C. F. Davis & Co.; one mile above the mouth of the river; known as the Fremont water-power; formerly, but not now, used; head, twelve feet.

The mill on the Clearwater river at Fair Haven has about ten feet head.

Crow River flouring mill, J. P. Appelgreen; on the North branch of the Crow river in the east edge of the village of Paynesville; head, fourteen feet; three run of stone.

Beckley & Phipps' flouring mill; on the same stream one and a half miles below the last, in the west edge of section 10, Paynesville; head, eight feet; three run of stone.

Building stone. The Archæan rocks, chiefly syenite, described in an earlier part of this chapter, have been quarried at numerous places in Saint Cloud, Le Sauk, Saint Augusta, Rockville and Wakefield; and in many localities they are admirably adapted for this use. At present, however, the most extensive quarries of these rocks are east of the Mississippi in Benton and Sherburne counties, within a few miles from Saint Cloud. The boulders of the drift have been very commonly used by farmers for cellar-walls and foundations, well-curbing, and other purposes.

Lime. In many portions of Stearns county boulders of magnesian limestone have been burned for lime to supply the local demand, the annual product in no case exceeding a few hundred barrels, but in the aggregate amounting to several thousand barrels. The following is a list of these lime-burners, noted during the examination of this county in 1880 and 1881.

In section 30, Maine Prairie, A. B. and H. J. Hicks, about 400 barrels yearly, sold for $1.40 per barrel at the kiln. All the limestone boulders that they collect yield white lime. The largest block found measured 12 by 6 by 6 feet.

In Luxemburg, N. Lardy in section 4, John Raush in section 11, and several others.

In Eden Lake, B. Pirz in the N. W. ¼ of section 5, during ten years or more, and John Leyendecker in the N. E. ¼ of section 6, beginning in 1880; white lime, $1.25 per barrel at the kiln. About a twentieth part of the boulders in the morainic hills in these sections are limestone, the remainder being mainly granite, syenite and crystalline schists.

In Munson, John Corde in section 8.

In Farming, John Ludewitz in section 27, John Clouse in section 28, and others; selling at $1.35 to $1.50 per barrel.

In Zion, Christian Lauer and Michael Hammer, both in the east half of section 6.

In Saint Martin, David Smith in section 7.

In Oak, Henry Welle in section 14, and Joseph Haas in section 21; selling at $1 to $1.25 per barrel.

In Spring Hill, C. Schoenborn in the S. W. ¼ of section 24, and Joseph Gau in the N. E. ¼ of section 27, the latter obtaining the stone mostly from a large mass, fifteen feet or more in length, buried in the drift excepting a small point.

In Melrose, A. J. Petrie in section 20, and John Dwyer in section 30.

In Getty, G. Gilbertson in section 19, and George Barlow in section 22. The largest limestone block found by Mr. Gilbertson measured 8 by 5 by 4 feet.

In Sauk Center, L. M. Thomason in section 22. Generally through the west part of this county about one in a hundred of the large boulders is limestone, one in twenty approximately of the smaller boulders, and a still further increased proportion of the gravel.

Deposits of marl, formed by fresh-water shells in lakes and sloughs, were used many years ago for making lime in the south edge of the city of Saint Cloud, and at another locality about half-way from Saint Cloud to Clearwater. The marl was moulded somewhat like bricks and then burned.

Bricks. In the south part of section 22, Saint Cloud, brick-making was begun in 1861, and continued several years; since which time little was done till 1881, when Greven & Lommel made 450,000 bricks here, selling at $8 to $10 per thousand in Saint Cloud. They are red and of good quality. The clay is dug from the western slope of a hill-side twenty-five feet higher than the road and depression thirty rods distant on the west. As seen in the excavation six feet deep, this clay is yellow, free from gravel or stones, yet with no marks of lamination, excepting in its upper part where it encloses thin layers of sand and fine gravel, by which also it is overlain.

In the S. E. ¼ of section 26, Saint Cloud, brick-making was begun in 1865, and has been carried on by William Kruegel since 1868. His product in 1881 was 400,000, sold for $7 to $8 per thousand at the kiln. These bricks are cream-colored, but reddish-tinted in the outer part of the kiln and greenish next to the fire. The excavation for the clay is about ten rods square and four to ten feet deep. About 1½ feet of black soil is removed; next is yellowish clay, levelly stratified, needing no sand for tempering, 5 feet; farther downward the clay is "richer," containing less fine siliceous silt, and gradually changes to a darker and bluish color, continuing, as ascertained by a well, to the depth of 17 feet; then a bed of sand is encountered, 6 feet thick; below which the blue stratified clay succeeds and extends 33 feet; lying on blue till, into which this well went 6 feet, to a total depth of 62 feet. This is on the east side of the road, on the level plain of modified drift which borders the Mississippi river.

On the west side of the road a little north of the foregoing, Frederick Kuhne began brick-making in 1881, producing 300,000 that year. The clay is obtained from the same excavation as the last, and the bricks are of the same character.

Red bricks have been made near the northeast corner of Collegeville, for the buildings of St. John's college. In the years 1876 to 1878 this work was by Greven & Lauer on land of the college in the north edge of section 1, using till or boulder-clay, with which sand was mixed in the proportion of one part to nine of the clay. In 1879 the site of this work was changed to the south end of St. Louis lake in the N. E. ¼ of section 2, about a mile south of the college, where it was continued by Joseph Lauer. The yearly product has ranged from 300,000 to 700,000.

About the year 1870 red bricks were made on the south side of the Watab river in the west part of section 21, Le Sauk.

A few years later red bricks were made on the southeast side of Rice lake in Oak township, two miles southeast from New Munich. In the last two localities the work was suspended after one year.

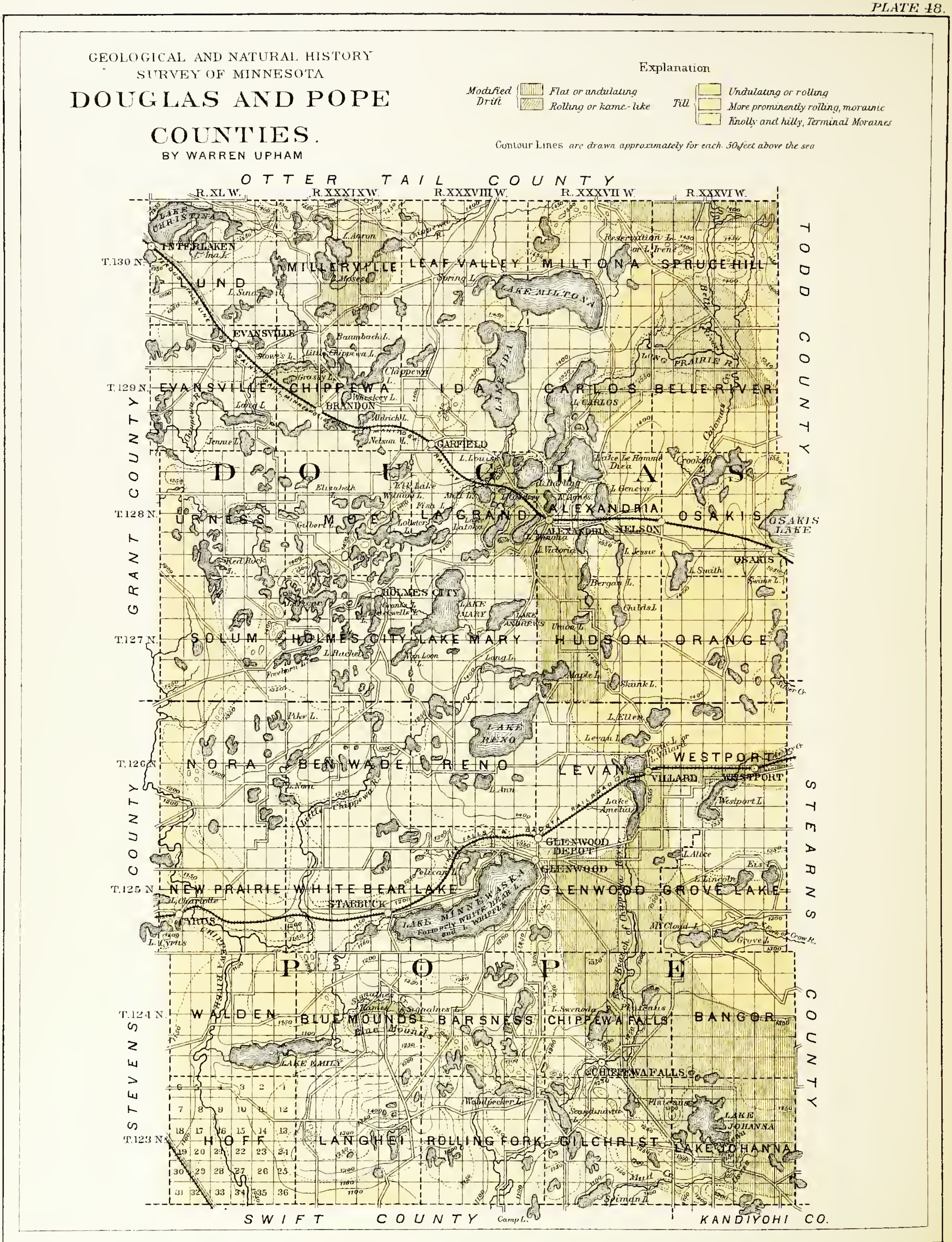
In Sauk Center brick-making by David J. Pangburn in the north part of section 34, three and a half miles south from the village and about a half mile southwest from the Sauk river, was begun in 1875. His yearly product is about 500,000, sold at $9 to $10 per thousand. Eight or ten men are employed. The clay used is yellowish, levelly stratified. No sand is required for tempering, and no limy concretions occur in the clay. About two-thirds of the kiln are red bricks; while one-third, subjected to greater heat in burning, are cream-colored.

Bricks are also made by Pangburn & Moore on the east side of Sauk lake, in the south edge of Todd county, about three miles north of Sauk Center.

ABORIGINAL EARTHWORKS.

Earthworks, like lines of fortification, three in number, each twenty rods or more in length, several rods apart and extending southeasterly, are situated about a mile north of Sauk Center, on the southeast side of the Little Sauk lake, which is now united with the Big Sauk lake by the flowage of the Sauk Center dam.

A natural mound of till, called Fairy Lake mound, rises some fifteen feet above the general level of the surrounding plain of modified drift on the south side of the Sauk river, in the S. W. ¼ of the N. E. ¼ of section 32, Sauk Center, about three miles northwest from the town. This mound is fifteen rods long and six rods wide, trending from west-northwest to east-southeast. Its outline seen at a distance is like that of a dome-shaped artificial mound; but, unlike the aboriginal mounds, it is oblong and composed of the unmodified glacial drift.



Julius Bien & Co lith

CHAPTER XVII.

THE GEOLOGY OF DOUGLAS AND POPE COUNTIES.

BY WARREN UPHAM.

Situation and area. Douglas and Pope counties (plate 48) lie in the west part of central Minnesota, about half-way between the Mississippi river and lakes Traverse and Big Stone. Glenwood, the county seat and largest town of Pope county, is about 120 miles west-northwest from Saint Paul and Minneapolis. Alexandria, the county seat and largest town of Douglas county, is 16 miles north of Glenwood. Other considerable towns and villages are Osakis, Brandon and Evansville on the Saint Paul, Minneapolis & Manitoba railway in Douglas county, and Chippewa Falls on the East branch of the Chippewa river in Pope county.

Each of these counties has a length of five townships, or thirty miles, from east to west, and a width of four townships, or twenty-four miles, from north to south. The area of Douglas county is 722.66 square miles, or 462,500.62 acres, of which 61,485.88 acres are covered by water; and the area of Pope county is 722.69 square miles, or 462,521.20 acres, of which 35,251.93 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Both these counties are wholly included within the basin of the Mississippi river; but about half of Douglas county, and nearly all of Pope county, send their waters to the Mississippi by the way of the Minnesota river.

The Long Prairie river, tributary to the Crow Wing, drains the northeastern and central portions of Douglas county, having its sources in lakes Miltona, Ida, Carlos, Le Homme Dieu, and others. Osakis lake, on the east line of Douglas county, is the head of the Sauk river. The west part of this county is drained by the Chippewa river, excepting its northwest corner, where lake Christina lies within the basin of the Pomme de Terre river.

In the east edge of Pope county Ashley creek, a tributary of the Sauk river, has its source in Westport lake; and the North fork of the Crow river takes its head-waters from Grove lake and others in Grove Lake township. The remainder of Pope county is drained by the Chippewa river, which flows southward through its west range of townships. The chief tributaries of this stream from Pope county are the Little Chippewa river, the creek which is the outlet of lakes Whipple and Emily, and the East branch of the Chippewa river, which flows south into Swift county and joins the main river near Benson.

Lakes of large and small size abound in these counties, especially in the region within ten or fifteen miles around Alexandria. The most notable have been described as follows by Rev. C. M. Terry.*

"The principal lake of Pope county is lake Whipple.† It has an average length of seven miles, and width of two miles. Its area is about 15 square miles. It is situated in the northern central part of Pope county. It lies very picturesquely at the foot of the great moraine, at an angle where its development is most typical. On the north and eastern sides the morainic hills rise irregularly above the lake to a hight of from 50 to 200 feet. At the northern extremity of the lake the quiet little village of Glenwood consists of a few houses at the foot of the bluff. Going up to the top of this bluff, which is more than 200 feet above the lake, one may enjoy as delightful a bit of natural scenery as there is in central Minnesota. From this summit the prairie stretches back to the north and west quite flat and featureless. Lake Whipple seems to occupy the bottom of a great basin around which the morainic hills of unusual boldness and hight gather on every side, except the west, where is the outlet of the lake into the Chippewa river. The depth of lake Whipple at the northeastern end, near Glenwood, varies from 12 to 30 feet. It is quite shallow along the western shores, and there are a number of sloughs and lakelets which drain into the larger lake. There are numerous springs about the northeast shore, and water is found in the wells of the village at depths of 14 to 40 feet. The water stratum is of sand underlying a bed of blue clay. The temperature of the water, on the 13th of July, 1880, was 77° F.

"Lake Reno, on the northern boundary of Pope county, is a prairie lake about four miles long and two miles wide. Its northeastern extremity is much narrower. It has an area of about six square miles. It is separated by a sand-bar from Maple lake on the north. The surrounding country is rolling prairie, nearly level. The banks of the lake show a subsoil of light yellowish clay. They are not more than 10 to 15 feet above the water, and usually slope gently back, without any abrupt or precipitous shores at any point. The lake has an even clay bottom, and in the central part has an average depth of about 20 feet. There are very few reeds or rushes and no islands. At the northeastern end there is considerable timber, the principal forest trees being the oak, maple and basswood. The larger portion of the surrounding country is prairie. The water is slightly alkaline and of a yellowish hue, characteristic of broad and rather shallow lakes which are easily stirred to the bottom by the winds. The temperature of the water on the 28th of August was 72° F. The outlet of this lake in high water is into the Chippewa river. Its inlets are temporary streams from the adjoining prairies and sloughs.

"The lakes of Douglas county are unsurpassed for the purity of their waters, the beauty of their scenery and general attractiveness. A glance at the map will show that there is a large number of them. But it is not the number so much as it is their beauty and variety which impresses anyone who studies them in detail.

* "The Hydrology of Minnesota," in the *Ninth annual report* of this survey.

† Formerly called White Bear lake, and recently lake Minnewaska.

"In the eastern half of Douglas county there is a chain of lakes remarkable for their purity, depth and beauty. They are all connected and lie within a radius of a dozen miles of Alexandria. Beginning with the most northern and the highest of the chain, they are Irene, Miltona, Ida, Louise, Mill, Andrews, Mary, Lobster, Fish, Latoka, Cowdrey, Darling, Union, Bergan, Childs, Victoria, Geneva, Le Homme Dieu, Carlos.

"Lake Miltona is the largest of the chain. It has an area of about nine square miles. It is six or seven miles long from east to west, and about two miles wide. It has two inlets, one at the eastern extremity and another at the northwestern. Its outlet on the southwestern side discharges into lake Ida. The lake has an elevation above the sea of a trifle over 1,400 feet. Its shores in many places are bold and rise abruptly 20 to 40 feet above the water. They are covered with forests except in a few places. The Leaf hills to the north, dun and hazy in the distance, are seen from the centre of the lake. There are large areas of the lake which are shallow, and the bottom is covered with a dense growth of aquatic plants. Although a number of soundings were taken in different parts of the lake, only one place of considerable depth was found where the line showed 80 feet of water; this was a little south of the centre. Other parts showed 30 to 50 feet, but the majority of soundings gave 14 to 25 feet. Owing to the amount of vegetation growing, the water is not as free from foreign matter as some lakes. It is, however, clear, sparkling with no tinge of yellow. There are some fine springs on the shores of this lake; and some stately forest trees, sugar maple, elm and basswood, are flourishing. The temperature of the water on the 10th day of August was 75° F. on the surface, 73.5° F. at the bottom. Air, 80° F.

"Next in size and order is lake Ida. It is four and a half miles long and one to one and a half miles wide. It has an area of about five square miles. It lies east of the central drift ridge, which divides the waters of the county. The surrounding country is massively rolling drift, and on the eastern side is well timbered. The water is very pure and crystalline. The shores are strown with pebbles and small sub-angular boulders. There are very few reeds and rushes. I found the temperature of the water on the 16th of August to be 73° F.; air, 81° F. The inlet of lake Ida is at the northern end, where it receives the surplus water of lake Miltona. The outlet is at the southeast corner, at Alden's flour and saw mills, whence it flows south.

"The charming little lake Latoka is only two miles from Alexandria. It is about one and a half miles long and half a mile wide. It lies in a deep and quite uniform basin. It has an average depth of fifty feet, the greatest being eighty feet. The bluffs around the north end at the outlet are from two to thirty feet high. The soil is sand and gravel, including some boulders. The water is remarkably pure and of a deep bottle-green color. The surrounding country is covered with forest.

"Lake Cowdrey, a few rods north of Latoka, is smaller in area but a very pretty lake. Here the surplus waters from some twelve or fourteen other lakes combine and send a deep strong current north to lake Darling.

"A sheet of water two miles long and a mile wide, surrounded by forests of stately trees, dry and bold shores, divided by a bar near the northern end into two basins, almost two lakes, this is lake Darling. The inlet at the southern extremity pours continually into this lake the surplus waters of a dozen others. The depth varies from sixteen to fifty feet. The water is clear and pure.

"Lake Victoria receives the drainage from half a dozen smaller lakes at the south. There are two arms, an eastern and western; both have inlets and combine to form the main body of the lake. The western arm is much the larger. In this basin the great mass of the water lies. Its depth, near the centre, varies from 40 to 50 feet. The east arm is 30 to 40 feet deep. Near the outlet the water becomes shallow and reeds are numerous. In the centre of the lower part of the lake the depths vary from 22 to 38. The water is not very pure; it contains a considerable amount of decaying vegetable matter, brought down from swamps and shallow lakes above. The shores of the Victoria are generally high and wooded. The banks, where exposed, are clay. A very short outlet, crossed by the Saint Paul, Minneapolis & Manitoba railway, brings us to the next link in the chain.

"Lake Geneva is nearly two miles long and half a mile wide. Its waters are clearer than those of Victoria. In some parts it is also considerably deeper. Soundings varying from 30 to 60 feet were made in the south half of the lake. There is clay in the surrounding bluffs, which rise 10 to 20 feet above the water. The railway has made a long, high 'fill' at the inlet. In consequence of these facts the water holds in suspension considerable earthy matter, giving it at times a faint yellowish tinge.

"One of the charms of this chain of lakes and the country adjacent is the presence of fine, large, forest trees which the ravages of the 'woodman' have not laid low. For this reason the shores of these lakes are particularly attractive as places of resort in summer, and are capable of such improvement at small expense as would make them delightful places of residence.

"Lake Le Homme Dieu has a quite irregular shape and lies in two distinct depressions of unequal depth. The long point that runs out from the west side is continued under water by a bar extending more than half way across the lake. In the southern basin, not far from the inlet, the water is from 60 to 75 feet deep. In various parts of this basin depths varying from 25 to 57 feet were found. The lower basin at the north end of the lake is larger and includes a deep bay on the west side, but on the whole this portion of the lake is shallower than the other.

"As a whole, it is one of the most beautiful sheets of water in Minnesota. The shores are moderately high and well wooded. It is separated only by a narrow bar from lake Carlos. The water is clear and pure. In this respect there is a gradual improvement as we proceed down the chain. Geneva is purer than Victoria, Le Homme Dieu is purer than Geneva, and Carlos is purest of them all. Temperature of lake Le Homme Dieu July 13th was 78° F.; air, 84°.

"Lake Carlos is the gem of this group of lakes. It is the last and lowest of the series. It is the immediate source of Long Prairie river, which forms its outlet at the northeast corner. It has two inlets, one from lake Darling at the southern extremity, and the other from lake Le Homme Dieu. It thus receives the surplus waters of all the other lakes north and south and the drainage of six townships. The lake in some places is 150 feet deep, and there is a channel averaging about 50 feet deep, extending the entire length of the lake. The deepest area is not far from the Le Homme Dieu inlet. There are shallow areas where the water is only 5 to 10 feet deep, further down the lake. It is about five miles long and a mile wide. The water is almost perfectly pure, of a deep bottle-green color. The color, however, varies with the sky and weather, and is sometimes a deep indigo and sometimes a light delicate blue. In this lake, as in many others which have been explored with the sounding line and other appliances for discovering what lies at the bottom, it was found that there are, under the level surface of the water, a variety of hill and dale, plateaus, ravines, abrupt declivities and gradual slopes very similar to the irregularities of the country around. Vegetation, too, flourishes beneath the waves as vigorously as on the main land, while the waters are thronged with fish of many species and of delicious flavor.

"There are many indications about the shores of these lakes of former higher levels of water. There are old beaches and half-obscured terraces which show that the lakes were connected at no very remote date. The whole of 'Alexandria prairie,' which lies between the two chains of lakes, is modified drift. The gravels, sands and clays are finely stratified and record the fact that at the close of the ice age some ancient river with gentle current flowed here, re-arranging and depositing in their present positions the materials which the glacier had brought down.

"On the eastern boundary of Douglas county, but lying chiefly in Todd county, is lake Osakis. It is about seven miles long. The southern part is a mile and a half to two miles wide. The northern part is narrow and deep. The depths at the upper end of the lake varied from 40 to 70 feet. Near Battle point 50 feet of water were found repeatedly. In the broader part of the lake there are large areas of shallow water, varying from five to fifteen feet, the average depth being about twenty-five feet. Around the southern part of the lake, the prairie slopes down gradually to the water's edge. Some of the shores are low and wet. At other points they are from ten to twenty feet above the water. The water varies in purity. In the deep parts at the north end it was quite pure. In shallow places and where the wind stirs the whole volume to the bottom, it has the yellowish hue characteristic of the more alkaline lakes

"Among the hills in the southwestern part of Douglas county are a multitude of small lakes, the largest of which is lake Oscar. The surrounding country is rolling, and there are some abrupt declivities and massive hills of drift, whose summits are from 50 to 150 feet above the lakes. There is a fringe of oaks about the lake, and a forest on the northeast stretches away to Alexandria and beyond. Toward the west and south lies a prairie country. The outlet of lake Oscar, in high water, is into the Chippewa river. Its only tributaries are other and smaller lakes. The basin is subdivided by various points and bars. The outlet is very irregular. This interlocking of land and water gives the most charming scenery. The shores are bold, being in several places 30 to 40 feet above the water. The lake is about 30 feet deep in its largest basin, growing shallower, of course, about the shore's points. The temperature of the water was 75° F.; and of the air, 58° to 80° F.

"In the extreme northwestern part of the county is lake Christina, which has an area of about six square miles, but is very shallow. The water is decidedly yellow and muddy. It is full of reeds and rushes. Its shallow depths and the rills and runlets pouring down from clay deposits keep it looking very much like Missouri river water. It is rather exceptional in this respect among the lakes of this region."

Topography. The south edge of the great terminal moraine called the Leaf hills extends into Lund along the north side of lake Christina, and into Millerville north of lakes Moses and Aaron. Its elevations in these townships along the north line of Douglas county are 100 to 250 feet above the lakes, or 1,300 to 1,600 feet above the sea.

At the highest point of the Leaf hills in Otter Tail county, fifteen miles south of the Leaf lakes, a morainic belt branches off nearly at right angles from the range of the Leaf hills and extends southeast into Douglas county. In the first few miles this moraine decreases in hight from 200 to 75 feet. At the north line of Douglas county it divides into two divergent belts, both showing a rough and broken surface, though the hills of each are only 75 feet or less in hight. One of these continues southeast and east through Spruce Hill township into Todd county; the other runs south-southwest to the northwest side of lake Miltona, along the west side of lake Ida, by Elk lake and the west part of lake Lobster, to the conspicuous hills, about 150 feet high, at the southwest corner of Moe. Each of these belts averages about one mile wide. The latter in its farther extent, seems to lead by a continuous course from the prominent Leaf hills to the almost equally noteworthy morainic range which extends through a distance of forty miles in southern Pope and northern Kandiyohi counties.

From the hills in Moe and the northeast part of Solum, lying on the north and west sides of lake Oscar, this terminal moraine, seldom much elevated above the adjacent country, but distinguished by its irregular hills and hollows, continues with an average width of about one mile, first southwest and south twelve miles to the bridge across the Chippewa river in section 32, Nora; then southeast, east, and east-northeast eighteen miles, passing along the north side of lake Whipple to Glenwood. It will probably be found traceable, also, by low knolls and ridges, from the bridge in Nora southeast to the hills in Blue Mounds township. About three miles southwest from the course of this moraine, a roughly broken tract of morainic hillocks and ridges was noted in section 30 and 31, New Prairie.

On the north side of lake Whipple (also called White Bear lake, or, more recently, lake Minnewaska), within a half mile or so back from its shore, very irregular morainic bluffs rise 150 to 200 feet or more. This ascent forms the margin of a gently undulating plateau which extends indefinitely northward, with an average elevation about the same as the top of these bluffs. At Glenwood the moraine bends southward around the east end of the lake, and thence it appears to be represented by prominent hills along the line between Barsness and Chippewa Falls, joining the well-marked morainic range of southern Pope county at a point ten miles south of Glenwood.

The township of Blue Mounds takes its name from the hills of this moraine, which rises into prominence about two miles northeast from the east end of lake Emily, and extends in a range of very irregular contour, 150 to 200 feet high, or about 1,250 to 1,350 feet above sea-level, east along the south side of Signalnes creek, east-southeast through Barsness, by the north side of Woodpecker lake, and between Scandinavia lake and Chippewa Falls, and thence southeast to the south side of Lake Johanna township, where it enters Kandiyohi county. The road from the west end of lake Whipple to Benson first crosses massively hilly land, 150 feet high, then descends about 100 feet to Signalnes creek, and next climbs about 125 feet among the picturesque ridges and hillocks of the moraine, reaching a point only 30 or 40 feet below its highest summits, which lie within one and a half miles eastward. The range here consists mainly of steep ridges of variable hight and length, sometimes a half mile long, running from west to east, with many enclosed irregular hollows. The road from Glenwood to Benson also passes over high swells north of this moraine, whose short, prominent west-to-east ridges it crosses in sections 20 and 29, Barsness. A beautiful little lake is seen here in a deep hollow of these hills below the road at its west side. Upon reaching the top of the moraine by these roads, one unexpectedly discovers yet higher land within a few miles at the south and southwest, where the north part of Langhei consists wholly of massive swells and hills of till, 50 to 75 feet above the enclosed depressions and lakelets. The highest portion of this area, in section 11, rises fully 100 feet above the moraine, or about 1,450 feet above the sea. The view from it southward and westward overlooks a gently undulating, but in the distance apparently level, tract, 300 to 400 feet lower, extending to the horizon. On the western slope of this highland, typically morainic contour in very irregular knolls was observed in or near section 18, Langhei.

The western and southern part of Chippewa Falls gradually becomes more and more hilly as we approach the morainic series at the south and west sides of this township. From Pope summit, a quarter of a mile north of the village and about 125 feet above the dam, the northwest to southeast range of the terminal moraine is seen rising to about equal hight two miles farther south. This belt of drift hills crosses Gilchrist southeasterly, and in section 5 of this township is itself crossed by the East branch of the Chippewa river. Again, in sections 29, 30 and 31, Lake Johanna, it is intersected by Mud creek. At the southwest side of lake Johanna a prominent mass of highland rises 125 feet or so above this lake. Its southwest margin, in section 30, descends in rough and broken morainic outlines, forming a part of this series. Here and in its farther course through Kandiyohi county, its highest points are about 1,250 or 1,300 feet above the sea, being 75 to 100 feet above the general level.

Most of northwestern Douglas county, between the Leaf hills and lake Christina on the north and the moraine that extends from lakes Miltona and Ida southwest to lake Oscar, is prominently rolling till, rising with smooth slopes in swells 30 to 50 feet above the depressions and lakes. The most rolling portion of this area is found in the west part of Ida and on a belt several miles wide next southwest from the Saint Paul, Minneapolis & Manitoba railway. Northwest from Brandon station a tract of moderately undulating and partly level gravel and sand, belonging to the modified drift, extends to the Chippewa river; and in Millerville nearly level modified drift extends two or three miles south and east from lake Moses, having a hight of 20 to 40 feet above this lake. The same formation of gravel and sand continues northward on the east side of lake Aaron to the moraine, but in this portion it has a moderately undulating surface.

The southwest edge of Douglas county, west and south from Red Rock lake, is a somewhat lower and gently undulating expanse of till. In the south part of this county, southeast from the moraine, Holmes City, Lake Mary and the west half of La Grand are undulating or rolling till, with elevations 20 to 40 feet above the hollows. The morainic hills of till west of lake Ida and north of the west part of lake Miltona, 75 to 100 feet high, are quite in contrast with the moderately undulating or often nearly level till which covers central and southeastern Miltona and continues thence south through Carlos and Alexandria, the east part of Hudson, the south part of Belle River, and Osakis and Orange.

In northeastern Miltona and Spruce Hill the morainic belt consists chiefly of kame-like, short, disconnected ridges of coarse gravel, 20 to 30 or rarely 40 feet high, most frequently trending from west to east or approximately so. North and south of this belt are tracts of level modified drift, only 10 to 25 feet above the streams; that south of the moraine occupies the north half of Belle River township, and continues westward on the south side of the Long Prairie river to lake Carlos.

Another tract of modified drift, consisting for the most part of level or slightly undulating sand and gravel, extends eight or nine miles south from Alexandria, through the west half of Hudson; and the same formation with a more rolling surface, in swells and plateaus 25 to 50 feet above the depressions and lakes, also reaches three or four miles west and northwest from Alexandria, through the east half of La Grand. Kames of coarse gravel, forming short ridges, 10 to 30 feet high, were noted near the Maple lake school-house in section 29, Hudson.

In western Pope county the Chippewa and Little Chippewa rivers have cut valleys about 40 feet below the moderately undulating surface of the till on each side and from a fourth to a half of a mile or more in width, this area of bottomland being partly or wholly alluvial gravel and sand. The winding valley eroded in the sheet of till through the north part of Blue Mounds township by the outlet of lake Whipple or Minnewaska, is fully 100 feet deep and a third to a half of a mile wide. In section 8 the bottom of this valley seems to be till, with no considerable alluvial deposits; but at the mouth of the lake a level tract of gravel and sand a half mile wide borders the creek, with a hight only 5 to 10 feet above it.

The greater part of Pope county is undulating or rolling till, in smooth, broad swells 20 to 40 feet above the intervening hollows, and elevated 150 to 250 feet above the remarkable basin which holds lake Whipple. On the south and west borders of the county, however, the southwest part of Gilchrist, the eastern two-thirds of Rolling Fork, the south edge of Langhei, most of Hoff and Walden, and the southwest half of New Prairie, have only about the same hight as lake Whipple, but are otherwise like the higher areas in material and contour.

A very interesting tract of modified drift, six to eight miles wide, extends from Glenwood southeast into Stearns and Kandiyohi counties. It consists of stratified gravel and sand, in part undulating or rolling in smooth swells 25 to

40 feet above the depressions, in part forming level-topped plateaus 40 to 75 or even 90 feet above adjacent lakes, and in part having a flat surface only a few feet above the lakes, sloughs and water-courses. This tract includes much of Glenwood, the northeastern two-thirds of Chippewa Falls, the west and south portions of Grove Lake, and all of Lake Johanna township excepting the morainic belt in its southwest part. Its hight in Pope county is from 200 to 100 feet above lake Whipple, descending eastward. In a later part of this chapter, with the discussion of the origin and mode of deposition of this modified drift, a more detailed description of its contour will be given.

Elevations, Fergus Falls line, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Osakis	130.4	1342
Summit, cutting 7 feet; grade	132.4	1407
Nelson	135.9	1368
Summit, cutting 9 feet; grade	137.8	1423
Outlet from lake Victoria to lake Geneva, water, 1353; grade	139.0	1371
Summit, cutting 14 feet; grade	140.2	1414
Alexandria	141.4	1389
Long Prairie river north of Mill lake, water, 1347; grade	144.4	1365
Garfield	148.2	1415
Summit, cutting 13 feet; grade, highest on the line	149.7	1449
Aldrich lake, water, 1389; grade	151.7	1402
Brandon	153.8	1386
Chippewa river, water, 1337; grade	157.0	1367
Evansville	159.0	1351
Summit, cutting 30 feet; grade	160.0	1376
Outlet from lake Christina to Pelican lake, water, ——; grade	165.4	

Elevations, Little Falls & Dakota railroad (leased by Northern Pacific railroad).

From profiles in the office of S. D. Mason, engineer, Saint Paul.

	Miles from Little Falls.	Feet above the sea.
Sauk Center -	37.0	1232
Westport	47.8	1332
Ashley creek, a half mile below Westport lake, bottom, 1317; grade	48.7	1329
Villard	52.7	1358
Lakes Villard and Amelia, water, 1345; grade	54.2	1350
Summit, grade and natural surface	59.2	1413
Glenwood	59.6	1401
Rue's run, bottom, 1260; grade	61.7	1297
Trapper's run, bottom, 1143; grade	64.2	1169
Lake Whipple, water, 1131; grade	67.1	1142
Water station	68.3	1157
Starbuck	68.5	1159
Little Chippewa river, bottom, 1148; grade	72.7	1155
Summit, cutting 3 feet; grade	74.6	1183
Chippewa river, bottom, 1108; grade	78.3	1122
Cyrus	78.8	1135
Summit, grade and natural surface	82.4	1189
Pomme de Terre river, bottom, 1075; grade	86.0	1088
Morris - - - -	87.8	1134

Osakis lake is about 1,310 feet, and lakes Winona and Agnes, close west and north of Alexandria, are about 1,365 feet above the sea. The survey for the Little Falls & Dakota railroad determined the hight of Westport lake, about 1,320, lakes Villard and Amelia, 1,345, and lake Whipple, 1,131 feet. Lake Reno is approximately 1,400, lake Johanna, 1,200, and lake Emily, 1,080 feet above sea-level.

The highest land of Douglas county is on or near the north line of Millerville, which crosses the border of the Leaf hills, attaining at a few points a hight about 1,600 feet above the sea. The other portions of this county are from 100 to 400 feet lower, its lowest land being the shore of lake Christina, which is about 1,215 feet above the sea, or the valley of the Chippewa river at the southwest corner of the county, which has nearly the same elevation. Estimates of the average hights of the townships of Douglas county are as follows: Spruce Hill, 1,400 feet above the sea; Belle River, 1,340; Osakis, 1,360; Orange, 1,375; Miltona, 1,440; Carlos, 1,375; Alexandria, 1,380; Hudson, 1,390; Leaf Valley, 1,420; Ida, 1,425; La Grand, 1,390; Lake Mary, 1,400; Millerville, 1,440; Chippewa, 1,390; Moe, 1,420; Holmes City, 1,410; Lund, 1,330; Evansville, 1,350; Urness, 1,360; and Solum, 1,350. The mean elevation of Douglas county, derived from these figures, is approximately 1,385 feet.

In Pope county the greatest elevations are attained in portions of Levan and Reno townships and the highland in the northeast part of Langhei, which are 1,425 to 1,450 feet above the sea. The lowest land is the valley of the Chippewa river on the south line of Hoff, about 1,040 feet above sea-level. The average hights of townships are estimated as follows: Westport, 1,375 feet; Grove Lake, 1,325; Bangor, 1,275; Lake Johanna, 1,250; Levan, 1,400; Glenwood, 1,300; Chippewa Falls, 1,300; Gilchrist, 1,225; Reno, 1,380; Barsness, 1,280; Rolling Fork, 1,180; Ben Wade, 1,350; White Bear Lake, 1,260; Blue Mounds, 1,250; Langhei, 1,250; Nora, 1,300; New Prairie, 1,200; Walden, 1,140; and Hoff, 1,100. The mean elevation of Pope county, derived from these figures, is approximately 1,275 feet.

Soil and timber. The black soil, one to two feet thick, is the upper part of the glacial and modified drift covering these counties, thus colored and made fertile by the decay of vegetation during many centuries. The carbonates of lime and magnesia, in the form of magnesian limestone boulders, pebbles and fine detritus, are an important ingredient of the drift, contributing much to the productiveness of the soil, and also making the water of wells and springs hard. Alkaline matter is not present in appreciable quantity. Wheat and other grains, sorghum, potatoes and other vegetables, live stock, butter and cheese, are the chief agricultural products.

Douglas county is well supplied with timber, about half of its area being wooded. This forest extends from Miltona, Spruce Hill and Belle River, its most northeastern townships, southwestward to lakes Andrews, Mary and Oscar. Southeast of this belt, the south edge of Osakis and most of Orange and Hudson are prairie. In the northwest part of Douglas county a strip of timber two or three miles wide, consisting partly of oak openings, extends from lake Miltona westerly to Chippewa lake and into Millerville and Lund. Besides this, most of the lakes are fringed with woods.

Pope county is mainly prairie; but timber usually borders the lakes and the larger streams. It is wanting, however, along much of the course of the Chippewa river. Its heaviest growth is found on the chain of lakes in the east part of Levan, and on the shore and bluffs of lake Whipple. At the east end of this lake, one to two miles south of Glenwood, it has a width of nearly a mile. Small oaks and poplars cover considerable portions of the northern township of Grove Lake.

The forest about lake Whipple consists mostly of bur oak, basswood, elm, box-elder, green ash, silver and sugar maples, wild plum, poplar and cottonwood, the last being frequent along the lake-shore; and the shrubs include prickly ash, hazel-nut, smooth sumach, frost grape, and climbing bitter-sweet. Several trees and shrubs that are common in northern Minnesota reach their southern limit in Spruce Hill township, the most northeastern of Douglas county, namely, black spruce, balsam fir, white pine, and the beaked hazel-nut. In this township, also, the paper or canoe birch, balsam poplar and blueberries are plentiful, but they are rare or absent farther southwest.

GEOLOGICAL STRUCTURE.

These counties are entirely covered by the glacial and modified drift, and no exposures of the underlying formations have been observed during this survey. Mr. J. H. Kloos, however, in connection with his notes on the Cretaceous beds near Richmond in Stearns county, adds: "At only one more locality have I succeeded so far in finding the same clay. This is on the north shore of White Bear lake in Pope county, near Glenwood, a village situated forty-two miles west of Richmond, and seventy-five miles west of the Mississippi. Here it makes its appearance under a cover of drift, which must be at least 200 feet thick and in which all of the beautiful landscape has been shaped, which has made Glenwood a favorite resort for tourists and pleasure-seekers." It seems very probable that Cretaceous strata exist in the lower part of the bluffs bordering this lake, and that they may be exposed in some of the ravines. Considerable masses of lignite, from a few inches to about a foot in diameter, have been found occasionally among the gravel and boulders of the lake-shore. These were doubtless derived from seams of lignite in Cretaceous deposits contemporaneous with those seen in the neighborhood of Richmond; and such may form the bed of the lake and the base of its bluffs, covered superficially by drift fallen from above. Small pieces of lignite are also found frequently in the glacial drift of this region and of all western Minnesota, as by well-digging and railroad-grading. They show that much of this drift has been supplied by the erosion of Cretaceous strata; and the lumps of lignite found along the lake near Glenwood may have come thus, like the boulders on the shore, immediately from the glacial drift.

The thickness of the drift in Douglas and Pope counties is probably from 100 to 250 feet. Its bottom has not been reached by wells, and this estimate is derived from its known thickness on adjoining areas. The greater part of this formation is till or the modified glacial drift, called also boulder-clay or hardpan, deposited by the ice-sheet without modification by water. With this are associated beds of modified drift or gravel, sand and clay, which were gathered from the ice, assorted and laid down by the waters set free by glacial melting. The topographic features of the drift, excepting the belt of modified drift in eastern Pope county, and its composition or material, excepting the terminal moraines, have been sufficiently described in an earlier part of this chapter. Its modes of deposition remain to be discussed, together with the stages in the recession of the ice-sheet.

Terminal moraines. It seems proper to give here a somewhat detailed statement of the characters of the drift accumulations called terminal moraines, on account of a difference in opinion concerning the method of formation of the series of drift hills and ridges in Blue Mounds and Barsness.* To the writer this seems to be quite certainly a terminal (that is, marginal or peripheral) moraine formed on the northern border of the ice-lobe which extended from the Red river valley southeastward. Professor Winchell, on the other hand, attributes its formation to the action of waters flowing eastward along this course in a trough-like hollow enclosed on the south and north by confluent portions of the ice-sheet, which sloped down from each side to this line, making it an avenue of drainage. A brief general description of the distinguishing features of terminal moraines will also be further useful, because they form the most noteworthy part of the geography and geology of several counties, as Otter Tail, Becker, Todd and Morrison, which are the subject of later chapters in this volume.

The most conspicuous deposits of an alpine glacier are its terminal moraine, or the heaps of rock-fragments and detritus which it carries forward to its termination. This frontal line often remains at nearly the same place through many years. The flowing ice continues to this limit, where it is melted, and the materials which have fallen upon its surface from bordering cliffs, or which it has plowed up from below, are here left at its end in heaps, ridges and hillocks, of very irregular contour, due to slight retreats and advances of the ice-front, and of greater amount than the deposits which appear upon the area over which it moved, exposed when any climatal change causes the glacier to retreat a considerable distance. Across the northern United States, from Nantucket and Cape Cod to Dakota and farther northwestward in the British possessions, are found similar but much greater accumulations of drift which appear to have been amassed along the boundaries of the ice-sheet of the last glacial epoch.

Prof. T. C. Chamberlin's observations of the terminal deposits of glaciers in the Alps, examined for comparison with the terminal moraines of the North American ice-sheet, indicate very clearly a similarity of origin. He writes as follows:†

"The Rhone glacier surpasses all others visited in its instructiveness in relation to the drift deposits. After a course of nearly fifteen miles, it descends precipitously, like a gigantic frozen cascade, into the valley of the Rhone, where it finds a broader area and more gentle slope. Here its foot spreads out into a flat semicircular form. . . . It is now retreating at a rapid rate. . . . As it bears but little detritus on its surface, its abandoned ground moraine is well exposed to study. . . . The ground moraine here consists mainly of rounded and scratched boulders, gravel and sand, with but little clay, and only a small proportion of angular blocks that cannot be traced distinctly to the medial or

* Professor Winchell's description of the Blue Mounds ridges is contained in the thirteenth report.

† *Annual report of the Wisconsin Geological Survey for* 1878.

lateral moraines. The surface contour is slightly, though not conspicuously, ridged. The more abrupt side of these little ridges is toward the glacier, and their trend is in the main approximately parallel to the edge of the glacier, though sometimes notably oblique.

"If we now approach the foot of the glacier, we shall find this morainic sheet of detritus passing without notable change or interruption beneath the ice. The appearance is as though a stationary mass of ice had formed on the surface of a bed of boulders and gravel and was now quietly melting away.

"If we now turn to the sides of the valley, we shall see that up to a certain hight they are mainly bare of vegetation, and present a fresher and less weathered surface than the slopes above, as though the glacier had recently stood at that hight. If we glance down the valley, we shall see that the upper margin of this surface descends curvingly, much like the contour of the present foot of the glacier. If we descend the valley to the point where this reaches the plain, we shall find the ground moraine rising into a low, irregular ridge, which stretches in a broken curve across the valley. The material of this ridge is essentially the same as that of the ground moraine, save that there is noticeably more sand and gravel in proportion to the coarse material, and the whole is more thoroughly rounded. These remarks relate to the surface material. The superficial contour, however, assumes quite a different and distinctive aspect. Although but a diminutive ridge itself, not perhaps exceeding twenty feet in hight, its surface contour, instead of presenting a simple curving outline, exhibits a complex series of still more diminutive ridges, hills and hummocks, of irregular outline and arrangement, accompanied by correspondingly irregular depressions, some of which are filled with water and form miniature lakelets. The irregular outline and little islands of one of these made it almost a Lilliputian Minnetonka. Boulders are abundant in all portions on and in the ridge, as shown by the sections exposed by the outflowing streams, which also exhibit the confused unstratified condition of the interior. Locally, there are small patches of stratified material. The ridge is most abrupt on the outside or that away from the glacier, while on the inside it graduates, without any distinct line of definition, into the boulder sheet above described.

"This ridge presents a striking similitude to our Wisconsin Kettle moraine, and I think it may be safely said to be a miniature representative of the same phenomena.

"On the south side of the Rhone, at the foot of the acclivity, where the solar action is less effective than elsewhere, a considerable mass of ice has been left by the retreating glacier, and this is much covered by sand, gravel and coarse detrital matter. As the ice melts, it deposits its burden of rock-rubbish in an irregular, hummocky fashion, somewhat resembling that of the moraine above described, but without the ridgy characteristics of the latter. It is mainly interesting as illustrating the form of deposition of a superficial glacial accumulation where the ice lets it down by melting from beneath, instead of casting it over its extremity in the usual method.

"The terminal moraines of the Grindelwald glaciers are even more instructive by way of comparison with our drift moraines, because of the closer proximity of the successive ridges, and the greater similarity of the material, it being a limestone boulder clay, with some metamorphic erratics included, and some assorted detritus. Some of the moraine ridges are a pronounced boulder clay, while others are largely composed of boulders or gravel. On the inner moraine of the upper Grindelwald glacier, there is much fine gravel and sand in heaps and miniature ridges, presenting a very interesting phenomenon. The outer range is more massive than those of the Rhone glacier, and is very strikingly similar to the Wisconsin Kettle moraine in its superficial expression. The corresponding moraines of the lower Grindelwald glacier show the same features very neatly, and those of the Bois and other glaciers display like characteristics.

"So far as my observations went, the nature of the rock over which the glaciers passed was more influential in determining the proportion of clay, sand, gravel and boulders, than I had supposed. Where the rock was mainly granitic, the amount of clay was proportionately small, the detritus being mainly coarse sand, gravel and boulders. This was doubtless due to the difficulty of reducing the hard constituents of granite to powder. Where the glacial channel lay through schistose rocks, or limestone, there was a notably larger proportion of clay, and some of the moraines were a typical boulder clay."

The material of the terminal moraines of the ice-sheet which have been explored in Minnesota is nearly everywhere till, with scanty deposits of modified drift. The latter consists of obliquely and irregularly stratified gravel and sand, the gravel often being very coarse, with pebbles and rounded stones of all sizes up to a foot or more in diameter. It either occurs enclosed in the till, forming beds and masses of variable shapes from a few inches to several feet in thickness, or sometimes it is spread upon the surface and forms knolls and ridges. No considerable area or extensive portion of this formation is found to consist entirely of this modified drift, assorted and deposited in layers by currents of water, within this region; though at some localities in Dakota county, in Spruce Hill, Douglas county, and in the township of Blue Mounds, Pope county, it is in great part stratified gravel and sand, usually with numerous boulders enclosed and scattered over its ridges and hillocks. A notable contrast is presented by some other portions of these series of terminal drift deposits of the continental ice-sheet, as for a distance of eighty miles on Long Island, from Roslyn to Amagansett, where they are made up almost wholly, so far as can be seen on the surface and in excavations, of such stratified gravel and sand, with only rare boulders.

The till of the terminal moraines differs very noticeably from the more level areas of till which generally lie at each side; in that the former has many more boulders, and a much larger intermixture of gravel and sand than the latter. On an average, probably twenty times as many rock-fragments, both large and small, occur in the morainic hills and knolls as on the smoother tracts, and sometimes the ratio is a hundredfold. The smaller pebbles and stones have angular and unworn forms, or more frequently are rounded, probably by water-wearing before the glacial period, or show planed and striated surfaces, due to grinding under the moving ice-sheet. The large boulders are mostly less than five feet, but rarely are ten feet or more in diameter. In form they are subangular and of irregular shape, rarely showing any distinctly water-worn or glaciated surface.

In contour these deposits are very uneven, consisting usually of many hillocks, mounds and ridges of rough outlines and broken slopes, with enclosed hollows, which are sometimes nearly round but more generally have some irregular form, often holding sloughs and lakelets. The only indication of system appears in the frequently noticeable trends of the elevations and depressions in a direction approximately parallel with the course of the series.

It should be added that the ridges which occur as part of this formation differ from the ridges of interbedded gravel and sand called osars, in their material, which is usually boulder-clay or till; in their trend, at right angles with the course in which the ice moved, while series of osars extend nearly in the direction taken by glacial currents; and in their length, single ridges of the moraines being only from a few rods to a quarter of a mile or very rarely perhaps a half mile long, while a single ridge in a series of osars is generally longer, and is sometimes distinctly traceable ten or twenty miles. In this state, however, osars of similar extent with those of Sweden and Scotland, and those described in Maine by Prof. George H. Stone, in Massachusetts by Rev. G. F. Wright, and in New Hampshire by the writer, have not been found. The most notable osars observed in this survey are a very remarkable one in Bridgewater and Cannon City, Rice county, about five miles long, described and mapped on page 666 in vol. I, and the gravel ridges extending two miles in Lake Johanna township, to be described on a succeeding page in this chapter. Their origin seems to have been by deposition from glacial rivers, flowing between walls of ice, whose subsequent melting left these deposits in long, narrow ridges, with steep sides. The suggestion of McGee and Chamberlin is here followed, that the name *osars* should be applied to these long gravel ridges, and that the term *kames*, under which they have been included, should instead be limited to knolls, hillocks and short irregular ridges of gravel and sand, such as are scattered more or less frequently upon undulating areas of till, and are especially apt to form part of the terminal moraines. These likewise are the deposits of glacial streams walled by ice, but usually, as it would appear, of small size and short extent, as compared with the rivers by which osars were formed. Kames, as here restricted, were probably accumulated at the border of the ice-sheet in the hollows melted out where streams debouched from the ice to the open land.

Besides the very rough, knolly and ridgy portions of the terminal moraines, they have on some areas only a prominently rolling surface, moulded in smooth swells of moderately steep and gracefully curved slopes, also trending, wherever any uniformity is noticeable, in the direction of the series. Neither these nor any other drift accumulations observed in Minnesota have the smoothly oval contour of the remarkable lenticular hills of till, or drumlins, described by Prof. C. H. Hitchcock and other writers in New England, New York and Wisconsin; and the trends of these two classes of drift hills differ ninety degrees in their relation to the course of motion of the ice-sheet.

The hight of the morainic elevations above the intervening hollows is generally from 25 to 75 or 100 feet. The only district in this state where they are higher for any considerable part of the series is the Leaf hills, which through a distance of twenty miles rise from 100 to 350 feet above the adjoining country. Upon the Coteau des Prairies the terminal moraines lie on areas of highland, to the altitude of which they appear to add 75 or 100 and rarely 150 or 200 feet.

For agriculture the value of the terminal moraines is much less than that of the gently undulating till which generally covers 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 highly productive soil; while the portions which are too knolly and stony for desirable cultivation afford excellent pasturage. In some districts the entire morainic belt is in smooth swells, being all good farming land.

The origin of these series of drift hills is confidently referred to the action of the continental ice-sheet, accumulating them at its margin in successive belts, which mark the farthest limit reached by the ice in the last glacial epoch and lines where it halted or perhaps temporarily re-advanced during its final recession. Their reference to the agency of land-ice is required by the partly near and partly remote sources of their material; by its generally unstratified condition; by its transportation next to these hill-ranges in courses nearly at right angles toward them; and by the variable elevation of the series, conforming to all the irregularities in altitude of the region across which they extend.

In general, the material and contour of the morainic belts in Douglas and Pope counties present the same characters as in other parts of the state, agreeing fully with the foregoing descriptions. The contour of the drift hills under question in Blue Mounds and Barsness has been mentioned on a former page, being hillocks and short ridges, trending from east to west, in the same direction as the belt which they form. Their material is partly sand and gravel, commonly with frequent or abundant boulders, and partly boulder-clay or till. The shortness and the disconnected or irregularly interlocked arrangement of the ridges, their variable width and broken slopes, forbid their reference to such glacial rivers as deposited the prolonged narrow ridges called osars, and seem to prove that their accumulation, where they consist of sand and gravel, was by the waters flowing down from the melting surface of the ice-sheet along its margin. This mode of formation must also be attributed to the greater part of the morainic belt observed in Spruce Hill and the northeast part of Miltona, and to the upper portion of the bluffs at Glenwood. Boulders are usually present and at many places are very abundant in and on these deposits of gravel and sand in the morainic belts; but they are usually absent or rare in and on osars, wherever those peculiar gravel ridges have been observed by me, both in New England and Minnesota. Typical osars occur in Lake Johanna township, and a comparison of these with the hills of Blue Mounds and Barsness shows wide differences in material and topographic features, while the course of the former is from south to north, at right angles with the adjoining morainic belt. Moreover, this apparently typical moraine has been continuously explored in an unbroken course, with no abrupt turn, from Blue Mounds to Cape Bad Luck in Kandiyohi county and onward to the high morainic hills at the southeast corner of Wakefield in Stearns county, a distance of sixty miles.

Comparison and correlation with the morainic belts of other portions of the state indicate that the series of drift hills in Lake Johanna and Gilchrist is contemporaneous with the sixth or Waconia moraine and the seventh or Dovre moraine. The former is represented farther north by the drift accumulations along the line of Chippewa and Barsness and about Glenwood east and north of lake Whipple. The latter, or Dovre moraine, continues westerly through Barsness and Blue Mounds and northwest to Nora, where it curves gradually and thence runs northeast through Douglas county by lakes Oscar, Ida and Miltona. The lobe of the ice-sheet on whose boundaries these lines of knolly and hilly drift were formed, lay on their south and west side. At the time of the Waconia moraine the angle in the glacial boundary formed by the confluence of the ice-fields flowing from the west and those flowing from the north and northeast was probably near Glenwood, the northern ice terminating on the tract of rolling till that extends eastward from Glenwood and lake Reno into Stearns county, not distinguished by specially morainic contour. At the time of the Dovre moraine this northern ice appears to have reached only to Spruce Hill, its angle of confluence with the western ice-lobe being in the north part of Miltona. During the two stages next later in the glacial recession the massive Leaf hills were accumulated at the south end of the western ice-lobe, which in its earlier extent had covered the basin of the Minnesota river and stretched southward in Iowa to Des Moines.

Modified drift. Eastern Pope county contains several areas of modified drift within a few miles north and east from the terminal moraine, which appear to have been deposited by floods from a melting and retreating ice-sheet, occupying places where basins were formed in the dissolving ice near its margin. One of these areas of stratified gravel and sand forms an elevated plain a mile across at the southeast side of lake Johanna. Its material is in part very coarse gravel, containing subangular rock-fragments up to one foot or one and a half feet in size, but larger boulders are absent. In other parts it is fine gravel and sand. It is bordered on all sides by land 50 to 80 feet lower, and its southern portion is about 90 feet above the lake. It has a descending slope to the north, amounting to ten feet in its mile of extent. Another plateau of similar material, extent, hight, and slope of ten feet per mile to the north, occurs on the west side of lake Johanna; and a little farther north, in section 6, Lake Johanna, and section 1, Gilchrist, are others somewhat lower, also sloping northward. Slightly elevated plains of modified drift, 25 to 40 feet high, were observed also in section 23, and the southeast part of section 15, Chippewa Falls, in section 3 of this township and extending into section 34, Glenwood, and in the southeast part of section 22, Levan. These plateaus of gravel and sand have steep sides and nearly or quite flat tops. The intervening tracts are gently undulating lowland, also mostly modified drift, from 25 to 75 feet below these high plains. The origin of these deposits seems to have been from glacial melting, which washed away a portion of the drift material that was held in the ice sheet, and spread it upon these areas while they were still bordered by ice-walls. Their slopes in the vicinity of lake Johanna prove that the waters there flowed northward, while barriers of ice at the east and west prevented deposition on the adjoining lower land. As these beds lie in front of the compound Waconia and Dovre moraine, it appears that they are of earlier formation, belonging to the time of the recession of the ice from its fifth or Elysian moraine.

To this time also must be referred the associated gravel ridges or osars in sections 22 and 28, Lake Johanna, close east and south of the elevated plain of modified drift first described. These extend more than two miles, the most eastern ridge being continuous and unbranched along this whole distance. This varies from 25 to 75 feet in hight, attaining its greatest elevation in the S. E. ¼ of section 28, about a fourth of a mile east from Ole Olson's house. Its devious course from west to east and northeast through the south part of section 28, and its nearly direct north-northeast course thence through section 22, the shorter approximately parallel ridges on its west side, and the contiguous plateau, are mapped in fig. 30. These ridges are narrow and have very steep sides, nearly like a railroad embankment. In hight they have the usual variable profile; the ridge close west and east of Olson's is about 40 feet high; the main ridge a quarter of a mile south of Olson's is 50 to 60 feet high, but near the northeast corner of section 28 and farther north it is only 25 feet, or sometimes only 10 feet, above the marsh which borders it on each side. The material of these osars is mostly subangular coarse gravel with some layers of sand, shown to be stratified by excavations at Mr. Olson's. Rock-fragments occur in great abundance of all sizes up to about one and a half feet in dimension, but no boulders much larger were seen. Usually ridges of this kind contain a greater proportion of fine gravel and sand, but these closely resemble the first osars described in this country by Dr. Edward Hitchcock, and later by Rev. G. F. Wright, in Andover, Mass. The deposition of these gravel ridges, as before explained, was by glacial streams flowing in ice-walled channels.

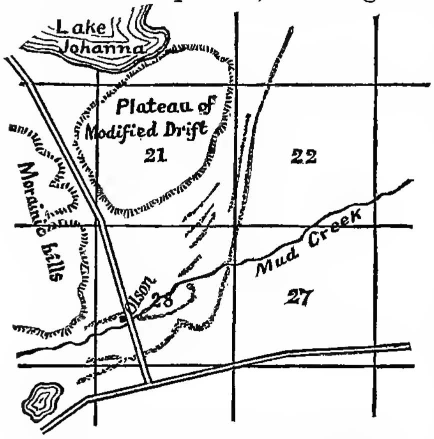


FIG. 30. OSARS AND PLATEAU OF MODIFIED DRIFT IN LAKE JOHANNA TOWNSHIP.

From the highest point of the main osar, probably 60 feet above the level of lake Johanna and 75 or more above Mud creek, all the view toward the east and northeast is an expanse of lower and moderately undulating or almost level modified drift. This is part of a remarkable tract of sand and gravel, varying from five or six to ten miles in width and extending nearly forty miles from Glenwood southeasterly to Paynesville in Stearns county, beyond which it continues by a narrowed belt to the Sauk river at Richmond. Its eastern portions have been described in the reports of Kandiyohi and Stearns counties. It slopes gradually eastward, having a hight in Glenwood 1,400 to 1,350 feet above the sea; in Chippewa Falls, 1,350 to 1,250; in Lake Johanna and the south part of Grove Lake, 1,300 to 1,200; in southwestern Stearns county and northeastern Kandiyohi county, 1,250 to 1,150; at Paynesville, about 1,150;

and at Richmond, approximately 1,125 feet. Besides its descent eastward it presents in general a descending slope from its southwest to its northeast side, amounting to 25 or 50 feet. Evidently the flow of the waters depositing these beds of modified drift was mostly from the terminal moraine which borders this tract on its west and south side along its whole extent. The plateaus and osars before described, and the prominently rolling areas of modified drift which occupy much of Chippewa Falls and Glenwood, rising in swells 20 to 40 feet above the depressions and water-courses, were deposited, as already shown, while the ice-front was retreating across this tract; but its many flat portions, with slight descent toward the east and north, were doubtless supplied from the glacial melting while the adjacent moraine was being accumulated. The top of the bluffs at Glenwood, which rise 225 to 250 feet above lake Whipple, are composed of this modified drift to a depth of about 40 feet, as is indicated by the many springs which issue along this line where the porous sand and gravel are underlain by the impervious till. Many large and small boulders are here enclosed within the modified drift and spread in profusion on its surface along the crest of the bluff, showing that the ice-sheet on the west abutted against this tract, mingling its coarse ice-borne freight with the stratified beds brought by the waters that flowed from its melting surface. Elsewhere boulders are absent or very rare on all this extensive tract of modified drift.

In the subsequent recession of the ice-sheet from northeastern Pope county and eastern Douglas county, by which its margin was withdrawn to the moraine of lakes Oscar, Ida and Miltona, and that of Spruce Hill township, further deposits of modified drift were made, including the belt of undulating or nearly flat sand and gravel, about one mile wide, reaching from lake Amelia and Turtle lake to the north end of Westport lake and continuing thence with less width along Ashley creek to the Sauk river; the plain in Hudson and Alexandria, with the connected area of plateaus, swells and kame-like accumulations in La Grand; and the plain bordering the Long Prairie river in Carlos and Belle River townships, with associated undulating and partly rolling and kame-like deposits in the south part of Spruce Hill. The terminal moraines in Todd county show, however, that the course of drainage could not continue northeastward in the valley of Long Prairie river, still covered by the ice-sheet, but was turned southward into the Sauk valley.

Much of Carlos township has a moderately undulating surface of till, underlain at the depth of 10 to 20 feet by a thick bed of sand, in which wells obtain water before reaching its bottom. Again, about one mile east of Alexandria a railroad-cut was seen to consist of stratified sand and gravel, having a vertical thickness of 20 feet exposed and continuing lower, overlain by a deposit of till 3 to 10 feet thick. These observations prove a considerable re-advance of the ice after it had once retreated, but both these movements probably took place within the same last glacial epoch.

A fault (fig. 31) was seen in a lenticular layer of dark laminated clay one and a half feet thick, enclosed in till, in the section cut for the railroad close northwest of Partridge brothers' brick yard in the north part of Evansville. The north end of this clay layer has fallen one and a half feet. This is five feet above the railroad track and about 35 feet below the surface, the whole section above and beneath the faulted clay being till.

FIG. 31. FAULT IN LENTICULAR LAYER OF CLAY, ENCLOSED IN TILL, EVANSVILLE.

Mean elevation due to underlying formations. The grand topographic features of this district, as the highland in Langhei and the depressions occupied by lake Whipple and lake Christina, are doubtless due to the contour of the formations, probably Cretaceous, which underlie the drift deposits. Erosion during the long Tertiary ages had probably sculptured the strata that then formed the surface in massive hills and elevated areas resembling the buttes and mesas of the west, divided by basins and channels sometimes several hundred feet lower. Such preglacial contour, though partially planed down and filled up by the erosion of the ice, still determined the mean elevation of the enveloping drift-sheet, giving in this district the beautiful scenery of Glenwood and Langhei, and in southwestern Minnesota the majestic Coteau des Prairies.

Boulders of magnesian limestone, like that outcropping near Winnipeg in Manitoba, are frequent in the drift throughout these counties, perhaps making on an average a twentieth part of the rock-fragments over one foot in size. Occasionally very large slabs and blocks of it are found, measuring ten or twenty feet in length. A much larger proportion of the gravel is this limestone, which makes about a third on the shores of Westport lake, and about half at the mouth of lake Whipple.

The other boulders and gravel are chiefly crystalline rocks, as granite, syenite, gneiss, and micaceous and hornblendic schists. The largest mass of this kind observed was a boulder of flesh-colored granite, 12 by 9 by 3 feet in the size of its visible portion, with perhaps as much more under-ground, lying in the northwest part of section 13, Langhei, a few rods north of the road. It is 40 or 50 feet below the highest land of this township, being on its southern slope. This kind of granite, however, does not appear to be specially abundant in the drift. No other boulder of the crystalline rocks larger than 5 to 7 feet in dimension, was noticed in these counties.

Ice-formed ridges of gravel and sand, sometimes with numerous boulders, occur in many places on the shores of lakes, usually where the water is shallow and the adjoining land low, being quite often a marsh scarcely higher than the lake, above which the ridge has a hight of three to six or seven feet, with a width of three to six or eight rods. Such ridges were seen on the southeast side of lake Moses in Millerville; at the mouth of Little Chippewa lake in section 9, Chippewa; along a distance of one and a half miles on the west side of the north part of lake Amelia and between this and Turtle lake, which were united before the formation of this ridge; south of the west part of Grove lake; and on the shore of lake Whipple a quarter of a mile west of Glenwood.

Wells in Douglas county.

Osakis. Wells in the village go 30 to 80 feet in till, which is yellowish to a depth of 10 or 20 feet and dark blue below. Water is found in thin veins of sand, from which it usually rises to a permanent level ten to twenty feet below the surface. In Andrew Thobiason's well, 78 feet deep, it rose 65 feet. Mrs. Tannehill's well, about 60 feet deep, at first had an artesian flow; this well became partly filled with quicksand, diminishing the supply of water, so that it now stands seven or eight feet below the surface.

George Fairfield; sec. 19: well, 66 feet; soil, 2; yellowish till, 12; and dark bluish till, 52, at which depth the boring was stopped by a boulder; the water of this well seeps mostly from the lower part of the yellowish till, which was thought to be harder than the dark till below. Knut Smith's well, in the south part of the same section, 28 feet deep, was soil, 2; yellow till, 12; and harder blue till, 14; water seeps mostly near the bottom of the yellow till.

William McSevanny; sec. 29: well, 35 feet; soil, 2; yellow till, 8; and blue till, 25; to sand, from which water rose thirty feet.

Orange. Lloyd D. Fairfield's well in the northwest part of this township, on a kame-like swell of the prairie, went 25 feet in sand and fine gravel; water abundant. About ten rods from this, another well on lower land, 16 feet deep, was yellow till, 8; and blue clay, probably till, but containing scarcely any gravel, 8; to sand, from which water rose six feet.

Carlos. Several wells in this township, after going through 10 to 20 feet of till, find a thick deposit of sand below.

Alexandria. Wells in the southwest part of the village go 15 to 40 feet in sand and gravel, sometimes finding a sufficient supply of water at the bottom of this modified drift, but in many cases needing to be dug 5 to 20 feet into the underlying till, to water-bearing veins of sand. A well in the east part of this village, 70 feet deep, was yellowish till, 55 feet, with seeping water in its lowest ten feet; then, blue till, 10 feet; succeeded by a layer of gravel, 8 inches thick, from which water rose twenty-six feet; this well was bored 4 feet farther in blue till below the gravel.

Hon. Fred von Baumbach's well, on the west side of lake Agnes, is 37 feet deep, being sand and gravel, 34; yellowish clay, 1; and nearly white clay, 2 feet and continuing below; water comes at the depth of about 25 feet, nearly at the level of the lake.

A well in the northeast part of this township, five miles from the village, went 45 feet in yellow till and 70 feet in blue till, obtaining no water. About half a mile east from this, Ole Flodin's well, 55 feet deep, was yellow till, 45 feet; then one side of the well was sand and the other side till for about 6 feet; below which the entire section was sand, 4 feet and continuing lower, containing plenty of water. Again, about half a mile east from the last, Mr. Grew's well, 95 feet deep, was yellow till, 35, and blue till, 60 feet, to sand from which water rose sixty feet. These three wells are on approximately level land probably not differing ten feet in hight.

For all the foregoing notes of wells in Alexandria, and for others in other townships of this county, and in Otter Tail and Becker counties, I am indebted to Mr. Henry H. Russell, of Alexandria. Mr. Russell has never found fossils during his very extended experience in well-making.

Hudson. A. R. Plymate; sec. 6: well, 13 feet, all gravel and sand.

Marden Brown; sec. 21: well, 11 feet, on a swell seven feet above adjoining lakelets and sloughs; coarse gravel, 9 feet, with a large supply of water in its lower two feet; and peaty mud, 2 feet, lying on a light green clay.

J. O. Kellogg; north part of sec. 29, about 25 feet above Maple lake; two wells, one 64 feet deep, the other 75 feet deep, found soil, 2 feet; sand and gravel, about 6 feet; and only till below, all very hard and requiring to be picked, excepting its upper ten feet; the only water found is the scanty amount that seeps in near the surface. This till contained two pieces of lignite, one being six inches in diameter, about forty feet from the surface. Most of the wells in this neighborhood encounter only stratified sand and gravel, in which water is obtained in abundance at depths varying from 15 to 30 feet.

Orange Mattison's well, 35 feet deep, in the south edge of sec. 35, has an artesian flow of water.

Leaf Valley. Major Flint's well, 55 feet deep, near the post-office, is yellow till, 25, underlain by sand, 30 feet and continuing deeper, with water in its lower part.

Sloughs in some parts of this township have been found to be underlain by blue clay, probably till, 8 to 15 feet; dry sand, 6 to 10 feet; clay, 1 to 3 feet; and wet sand beneath. Perhaps it may be practicable, in some cases, to drain them by boring to the layer of dry sand.

Ida. Wells in this township are mostly till, occasionally underlain by thick beds of sand.

La Grand. James F. Dickens; in the N. W. ¼ of sec. 3, a rolling and hilly area: well, 42 feet; yellow till, 10; and stratified gravel and sand, 32, to water. A half mile farther west, Mr. McCord's well was nearly the same, but penetrated to dark bluish till below the gravel and sand, after getting plenty of water.

Chippewa. Peter O. Thompson; S. E. ¼ of sec. 24: well, 112 feet; yellow till, 40; softer, sticky, dark blue till, 40, containing occasional stones and numerous small pieces of lignite, but only very scanty intermixture of fine gravel and sand; dry sand, 2; and blue till, 30, more sandy and gravelly, harder and lighter in color than above, destitute of lignite; no water was obtained.

Holmes City. Isaac Isaacson; sec. 23: well 65 feet; yellowish till, 20; bluish gray till, 30; and stratified clay and sand, 15, its lowest portion being dry sand; no water.

William H. Guiles; also in sec. 23: well, 84 feet; yellow till, 40; blue till, 30, like that at the same depth in Mr. Thompson's well in Chippewa; and bluish quicksand, 14 feet and continuing lower, full of water, which rose above the quicksand thirty-six feet.

Harrison Guiles' well, about two miles northeast from the last, went in similar deposits of till 66 feet, at which depth water under great pressure burst up and rose suddenly about forty feet to its permanent level.

Evansville. Richard Partridge; sec. 7: well, 48 feet; soil, 2; yellow till, 8; sand, ½ foot; gray till, 8; dark bluish till, harder, 30; the only water seeps in the upper part of the well.

Urness. Andrew J. Urness; sec 13: well, 25 feet; yellow till, 12; much harder blue till, 13, and extending lower; water comes mostly from a thin streak of sand sixteen feet below the surface.

Wells in Pope county.

Westport. Samuel D. Sheets; sec. 19: well, 15 feet, all gravel and sand.

A. M. Judkins; S. W. ¼ of sec. 30: well, 57 feet; soil, 2; yellow till, 35; sticky blue till, 20, and extending lower; water seeps very scantily, an insufficient supply. A second well only four rods northwest from this, was the same to the depth of 35 feet, where a vein of sand was struck, containing a large flowing stream of water, which rose six feet. These wells show that sometimes good water-bearing veins are very narrow. At S. G. Anderson's, about thirty rods farther west, overlapping modified drift forms the surface, the section of a well 51 feet deep being soil, 2; sand, 7; and yellow and blue till, 41; to quicksand, with water, dug into one foot and extending lower.

Grove Lake. A. D. Falkner; N. W. ¼ of sec. 20, in the northern township: well, 26 feet; soil, 2; all sand and gravel below; some of the layers contain pebbles up to six inches in diameter.

Edmund Meagher; S. W. ¼ of sec. 36, also in the northern township: well, 17 feet; soil, 2; yellow till, spaded, 12; sand, 3, and reaching deeper; water rose five feet above the sand. The wells of this vicinity are commonly curbed with pine, the decay of which sometimes makes the water offensive.

Lake Johanna. Peter Anderson; N. E. ¼ of sec. 5: well, 15 feet, all gravel and sand

Jacob Dickison; N. W. ¼ of sec. 6: well, 35 feet; soil 2; sand and gravel, 32; till, dug into only one foot; plenty of water.

Glenwood. John Hanzahan; sec. 1, southeast of lake Amelia: well, 35 feet deep, all modified drift, chiefly gravel and sand, with occasional layers of clay a few inches thick, most of the lower part being sand.

Knud Torgerson; S. E. ¼ of sec. 13, about one and a half miles southeast from the village and about 200 feet above lake Whipple, but 40 feet lower than land a quarter of a mile farther east: well, 18 feet; soil, 2; sand, 13; yellow till, 3; with water at the junction of the sand and till.

Gilchrist. A well in the S. W. ¼ of sec. 12, on the northern border of the morainic belt, was soil, 2 feet; and yellow till, 10 feet; with dark blue till below, not dug into.

Blue Mounds. Olaus Signalnes; N. W. ¼ of sec. 14: well, 17 feet; yellow till, 5 feet; and gravel and sand, 12 feet. This is on the undulating prairie, about a half mile north of the morainic belt.

Langhei. G. Tharaldson; N. W. ¼ of sec 1: well, 37 feet; yellow till, 25; blue till, 7; and sand, 5, with water.

Andrew Engebretson; sec. 12: well, 38 feet; yellow till, 26; and stratified gravel and sand, with thin streaks of clay, 12 feet.

Nora. Henry H. Belgum; sec. 28: well, 28 feet; soil, 2; yellow till, 20; very hard blue till, 5; sand, 1 foot and extending lower, from which water rose immediately six feet.

Hoff. Ole Swenson; sec. 2: well, 37 feet; yellow till, 20; much harder, dark blue till, 15; and sand, 2 feet and continuing deeper, with water.

Ole A. Anderson; S. E. ¼ of sec. 6: well, 40 feet; soil, 2; yellow till, 19; and sand and gravel, 19, to water.

Ole Nelson; S. W. ¼ of this sec. 6: well, 35 feet; yellow till, spaded, 30; and blue till, much harder, requiring to be picked, 5 feet and continuing deeper; water seeps, failing in dry seasons.

MATERIAL RESOURCES.

The soil and agricultural capabilities of these counties, and their timber, have been already noticed. In adaptation for profitable farming, which must continue to be their chief source of wealth, they are unsurpassed by any other part of the state or of the Northwest.

Water-powers. There are flouring mills on the Chippewa river in the north part of section 18, Leaf Valley, and at the mouth of the lake in section 31, Evansville. On the head-streams of the Long Prairie river are Alden's flouring and saw mills in section 25, Ida, at the mouth of lake Ida, and a mill in the northeast part of Holmes City, on the outlet of lakes Andrews and Mary.

In Pope county three water-powers are used for flouring mills on the East branch of the Chippewa river, as follows: West's mill, in the N. W. ¼ of section 11, Glenwood, three-fourths of a mile south of lake Amelia, having eight feet head; the Marlu mill, in the north part of section 26, Glenwood, having fifteen feet head; and at Chippewa Falls, having sixteen feet head. Another power, as valuable as the last, is said to be available a half mile below Chippewa Falls. Many other good water-powers wait to be utilized in these counties.

Building stone. No rock-outcrops occur in this district, but the boulders of the drift supply the needs of the farmer for coarse masonry, as foundations and the walls of cellars and wells.

Lime. Magnesian limestone boulders are used in many places for lime-burning, but in total only a few thousand barrels of lime are produced yearly. Most of the lime-burners are farmers, who supply the demands of their neighborhood, using kilns that hold 50 to 100 barrels, and often burning only one or two kilns in a year.

At Evansville the Partridge brothers burn lime, in connection with their business of brick-making, selling it for $1.25 per barrel. About half of their lime is white and the other half straw-colored. Charles Thompson, Gorand Kronberg, and I. C. Alstad have also burned lime in Evansville township.

Other lime-burners in Douglas county are John and Peter Schwartz in Millerville, Albert Lander in Chippewa, James W. Barr in section 35, Ida, and James F. Dickens in section 3, La Grand.

Lime has been burned in Pope county by Olaus Signalnes in section 14, Blue Mounds, and by several others within a few miles around lake Whipple.

Bricks. The Alexandria brick-yard, owned by John A. McKay, one and a half miles northeast from the village, was first worked in 1877. The section is soil, 1 foot; yellowish laminated clay, 3 feet; the same, with occasional sandy layers, about 4 feet in the excavation, thinning out farther north, but extending 12 feet below the surface in a well on the south. Below this modified drift the well went 4 feet in yellow till, under which was a vein of sand one inch thick, with water; then the well continued 40 feet lower in blue till, but no additional supply of water was obtained. No sand is needed for tempering, besides that which is interbedded with the lower part of the clay. The product was 200,000 bricks in 1878, and 500,000 in 1879, sold for $6 to $10 per thousand.

In section 2, Lake Mary, some three miles southwest from Alexandria, bricks were made by Mark Bundy from 1866 to 1880, producing about 75,000 yearly. Next below the soil is yellowish brown clay, 3 feet, making red bricks;

then, darker and bluish clay, more sandy, less sticky and plastic, 4 feet, making cream-colored bricks; succeeded below by bluish till, 8 feet and extending deeper. By mixing the upper and lower portions of this clay it is rightly tempered, with additional sand.

Bricks are made near the southwest corner of section 11, Holmes City, by Ole Olson, producing only a few thousand yearly. They are cream-colored, tinted reddish.

Richard Partridge and brother have made bricks since 1877 about a half mile northwest from Evansville, beside the railroad, which makes a cut 40 feet deep in the hill or swell on whose side the clay for this brick-making is dug. The railroad-cut is true till, yellow throughout, containing gravel and plentiful rock-fragments, including rarely pieces of lignite up to four inches in diameter; but in some portions next to the surface this deposit is nearly or quite free from gravel, and makes bricks of superior quality. The product in 1879 was about 40,000, sold at $10 per thousand.

In Glenwood bricks have been made by John Aiton since 1876. The clay occurs, as in Evansville and at Fergus Falls in Otter Tail county, on a hillside which in large part is till. It is in the northeast part of the village, about 50 feet above the lake. Next below the soil is almost horizontally laminated yellowish clay, of which a thickness of 4 feet is used. It contains in some portions streaks and tubular concretions of iron-oxide (limonite), and the lower part of this four feet is somewhat sandy. Still deeper the clay becomes more sandy and includes limy concretions. Fifteen feet below the surface, it is underlain by gray or bluish sand. No sand is mixed with the clay for brick-making. The product in 1879 was 300,000, sold at $7 to $10 per thousand. These are cream-colored bricks, varying in tint from greenish near the fire to reddish in the outer part of the kiln.

Springs. Many very large springs issue from the bluffs about Glenwood, mostly at a hight nearly 175 feet above the lake. The water of several is conducted by pipes into the village, furnishing an excellent supply of water for all purposes, including fire-hydrants. One of these springs formerly furnished the power of a grist-mill a half mile north of the village, a turbine wheel only eight inches in diameter being used, with forty-five feet head of water.

About two miles west of Glenwood, near Mrs. Esther Rue's house, are two sulphur springs within two rods of each other in somewhat marshy land between the bluffs and the lake, beside a little brook formed by these and other springs. White filamentous matter is seen in the sulphur springs, and their smell and taste are very marked. Near them is also a spring of clear water, and chalybeate springs occur about an eighth of a mile to the north in a ravine.

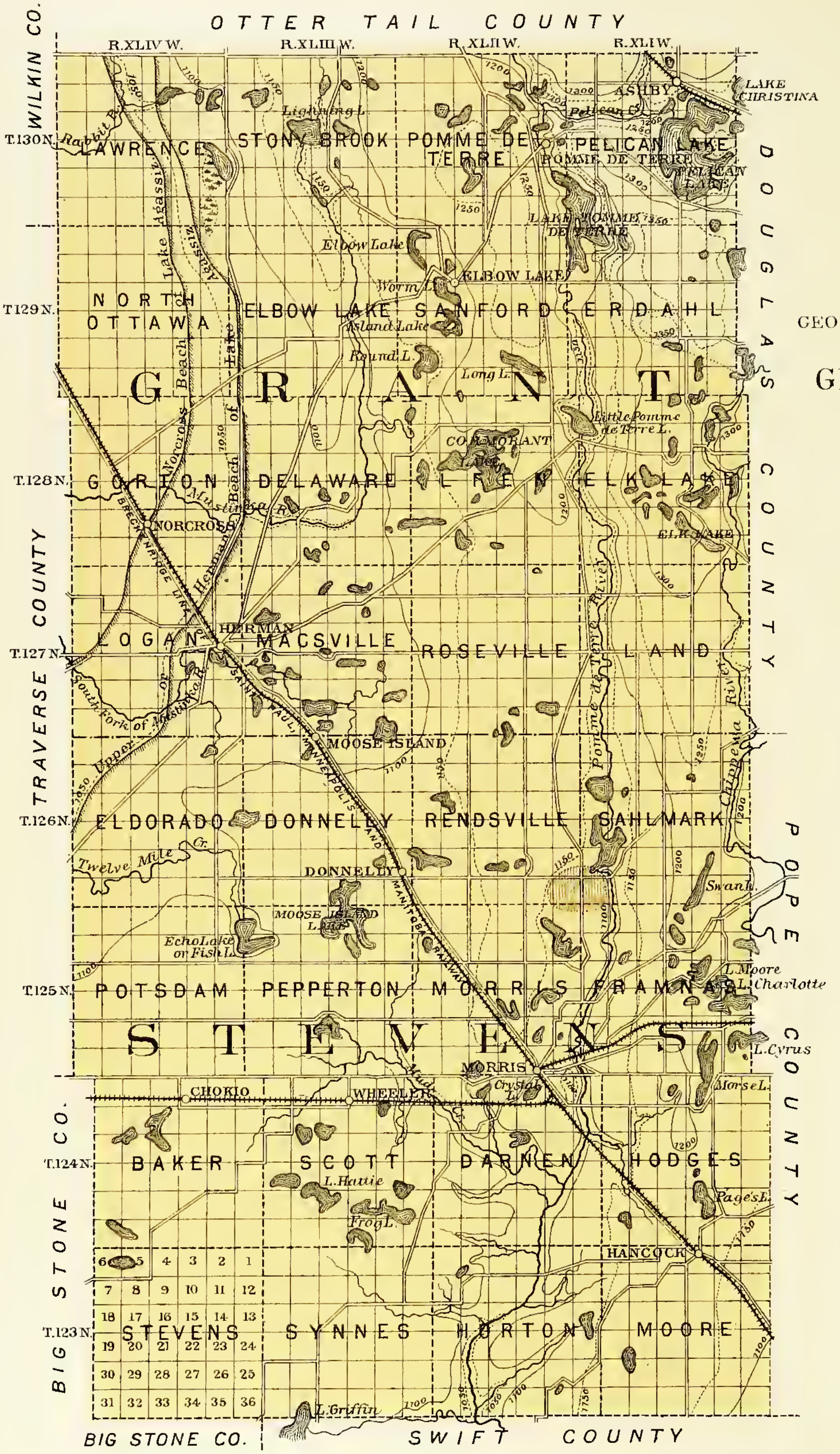
A quarter of a mile east from these is a very interesting limy spring, some twenty rods northwest from D. A. Bartke's house and on his land. This spring is a little rill in the woods, gathered from the ground of several square rods area, and flowing gently down perhaps ten feet in its first four or five rods. Then in two rods it falls fifteen feet, diffused over a steep mossy bank. Along all this distance and especially in the last two rods, the banks over which this water runs are composed of a calcareous deposit from it, encrusting mosses, sticks and leaves, so that this "petrified moss" is in some places several feet deep.

ABORIGINAL EARTHWORKS.

In the northwest corner of Alexandria, between lakes Carlos and Le Homme Dieu, on the west side of the road in heavy woods, is a steep mound, about fifteen feet high, which has been partly dug into and was found to contain bones. Near this are also two or three smaller mounds, about five feet high.

Numerous aboriginal earthworks were observed two or three miles west of Glenwood. On D. A. Bartke's land, some forty rods northwest from his house and about 75 feet above lake Whipple, are several mounds, mostly only about three feet high, but one of them has a hight of twelve feet. A half mile farther west, a mound six feet high is seen some fifteen rods north of the road, crowning a morainic knoll which is about 75 feet above the lake. Another artificial mound, of less regular form and smaller, lies some thirty rods southwest from the last, on the south side of the road, also on a morainic hillock, somewhat lower than the preceding. A quarter of a mile southwest from these and nearly the same distance south of the road is another mound about six feet high, situated similarly on the top of a knoll, probably 25 feet above the lake.

Four miles farther west, about thirty rods north from the outlet of lake Whipple and four rods northwest from the road, on the lowland only 10 feet above the lake, is a mound seven feet high. No others were seen in its vicinity.



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

GRANT AND STEVENS COUNTIES

BY WARREN UPHAM

Explanation.

- Beaches of Lake Agassiz.
- Modified Drift, flat
- Till
  - Undulating or rolling
  - More prominently rolling; morainic.
  - Knolly and hilly, Terminal Moraines

Contour Lines are drawn approximately for each 50 feet above the sea.

Julius Bien & Co. lith.

CHAPTER XVIII.

THE GEOLOGY OF GRANT AND STEVENS COUNTIES.

BY WARREN UPHAM.

Situation and area. Grant and Stevens counties (plate 49) lie in western Minnesota, in the second range of counties east from lakes Traverse and Big Stone. Morris, the county seat and largest town of Stevens county, is about 140 miles distant (in a direct line) west-northwest from Saint Paul and Minneapolis. Herman, the largest town in Grant county, is 19 miles northwest from Morris. Other important towns and villages are Hancock, Donnelly and Norcross on the Breckenridge line of the Saint Paul, Minneapolis & Manitoba railway; and Ashby, Pomme de Terre and Elbow Lake in the northeast part of Grant county, the last named being the county seat.

Each of these counties is a square, measuring four townships, or twenty-four miles, from east to west, and the same from north to south. The area of Grant county is 578.28 square miles, or 370,099.24 acres, of which 21,843.03 acres are covered by water; and the area of Stevens county is 571.48 square miles, or 365,748.00 acres, of which 10,411.81 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The west half of Grant county and most of the northwest quarter of Stevens county are included within the basin of the Red river of the North, being drained to lake Traverse by the Mustinka river and its tributaries. The rest of this district is drained to the Minnesota river, mainly by the Pomme de Terre, which flows very directly from north to south through the east half of these counties. The Chippewa river, however, flows nearly parallel with the Pomme de Terre river, and only four or five miles east from it, through the southeast edge of Grant and the northeast of Stevens; and the

Chippewa basin extends across the east boundary of Stevens county along its whole length.

Lakes are scattered numerously over all this district, excepting the west border of Grant county. They range in size from the smallest, a few rods in diameter, to Pelican lake, which covers approximately six square miles, in the most northeast township of Grant county, to which its name is given. Elk lake and Elbow lake in the same county also give their names to townships. Its other most noteworthy lakes are Pomme de Terre lake, through which the river of this name flows, Lightning lake in Stony Brook, Cormorant lake in Lien, and a group of a dozen small lakes within five miles east and southeast from Herman.

Among the principal lakes of Stevens county are two through which the Pomme de Terre river flows in Sahlmark, Swan lake in the southeast part of this township, lakes Moore, Charlotte and Cyrus, and Morse lake, in the east part of Framnas, Page's lake in Hodges, Moose Island lake and Fish or Echo lake on the northern borders of Pepperton, and Clear and Frog lakes in Scott.

Topography. Both these counties have mostly an undulating or rolling surface, rising in smooth, massive swells 10 to 30 or sometimes 50 feet above the hollows and lakes. Seen in a view of wide extent, however, the appearance is that of an approximately level plain. In southeastern Stevens county a specially prominent range of highland extends from north to south by Hancock, elevated 50 to 100 feet above the broad depressions on its west and east sides along the Pomme de Terre and Chippewa rivers. The valleys or channels eroded by these streams are from 50 to 75 feet deep, and vary from a quarter to a half of a mile, or rarely, where the Pomme de Terre river flows through lakes, one and a half miles in width.

The northeastern third of Grant county is more prominently rolling than most other parts of this district; and rough morainic knolls and hills border the north side of Pelican lake and extend west into the northeast corner of Pomme de Terre. These are the southwest edge of the great morainic tract called the Leaf hills. Within the limits of this county they attain only slight altitudes, 50 to 150 feet above Pelican lake and lake Christina, or about 1,250 to 1,350 feet above the sea.

In the western range of townships of Grant county, the area that was occupied by the glacial lake Agassiz, as described in a later part of this chapter, is characterized by a much more smoothed and even surface than the other parts of the district toward the east and south, this being the margin of the very flat, broad expanse which reaches thence west to the Bois des Sioux river and north along the Red river valley to Winnipeg.

Elevations, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

Fergus Falls line.

	Miles from Saint Paul.	Feet above the sea.
Outlet from lake Christina to Pelican lake, water, 1213; grade	165.4	1225
Interlaken	165.6	1228
Ashby	168.0	1291
Summit near Ashby, cutting 10 feet; grade	168.1	1294
Pelican creek, water, 1236; grade -	169.4	1249

Breckenridge line.

	Miles from Saint Paul.	Feet above the sea.
Hancock	150.09	1155
Summit, cutting only 1 foot; grade	151.64	1172
Pomme de Terre river, water, 1066; grade	155.49	1078
Junction of Brown's Valley branch	157.98	1120
Morris	159.09	1129
Summit, grade	161.00	1156
Donnelly	167.61	1124
New Moose Island tank	172.83	1093
Old tank and section-house	173.36	1085
Herman -	178.12	1070
Upper beach of lake Agassiz, cut 6 feet; grade	179.70	1060
Norcross, on lower beach of lake Agassiz -	183.00	1039
Mustinka creek, water, 1018; grade	184.51	1026
Gorton -	185.39	1022

Brown's Valley branch.

	Miles from Saint Paul.	Feet above the sea.
Junction near Morris	157.98	1120
Summit, cutting 4 feet; grade	160.0	1138
Another summit, with same grade	160.8	1138
Mud creek, water, 1076; grade	161.9	1103
Wheeler	165.2	1110
Chokio	171.2	1122

The highest land of Grant county, in Pelican Lake and Erdahl, is about 1,350 feet, and its lowest land, on its west boundary, is about 1,010 feet above the sea. Estimates of the average hights of the townships of Grant county are as follows: Pelican Lake, 1,275; Erdahl, 1,275; Elk Lake, 1,250; Land, 1,225; Pomme de Terre, 1,240; Sanford, 1,220; Lien, 1,180; Roseville, 1,160; Stony Brook, 1,160; Elbow Lake, 1,140; Delaware, 1,090; Macsville, 1,090; Lawrence, 1,050; North Ottawa, 1,035; Gorton, 1,035; and Logan, 1,050. The mean elevation of Grant county, derived from these figures, is 1,155 feet.

The highest land in Stevens county is in Sahlmark, about 1,250 feet above sea-level, approximately 200 feet above its lowest points, which are at its northwest corner and on its southern boundary where that is crossed by the Pomme de Terre river. Average hights of the townships are estimated as follows:

Sahlmark, 1,190; Framnas, 1,160; Hodges, 1,160; Moore, 1,140; Rendsville, 1,150; Morris, 1,140; Darnen, 1,110; Horton, 1,100; Donnelly, 1,105; Pepperton, 1,115; Scott, 1,120; Synnes, 1,120; Eldorado, 1,080; Potsdam, 1,110: Baker, 1,125; and Stevens, 1,130. The mean elevation of Stevens county, derived from these figures, is approximately 1,130 feet.

Soil and timber. A black soil extends everywhere one to two feet deep. This is the enriched upper part of the glacial drift, which below forms the subsoil, having a yellowish color, due to weathering, to a depth of 10 to 20 feet, beyond which it has a darker and bluish color. Clay, sand and gravel, with occasional boulders, intermingled in an unstratified manner (clay being the predominant ingredient), constitute the greater part of this formation. With this boulder-clay, till, or hardpan, as it is called, are associated comparatively thin and scanty deposits of stratified gravel and sand, which occur as layers in the till, or rarely in knolls or swells on its surface, also in flat tracts on the bottomlands of the larger streams, and in beach-ridges on the borders of lake Agassiz.

The chief agricultural staples are wheat, oats, corn, flax, sorghum, potatoes, hay, live stock, and dairy products. By reason of its fertility of soil, salubrity of climate, and abundant and excellent water, this is a very fine farming district; and it is everywhere adapted for cultivation and ready for the plow, excepting occasional sloughs of valuable marsh-grass and the steep bluffs that enclose the streams.

Both these counties are wholly prairie, with timber only in small groves beside many of the lakes and in a very narrow belt along portions of the rivers and creeks. Basswood, bur-oak, white and red elm, silver maple, box-elder, wild plum, green ash, hackberry, ironwood, poplar and cottonwood are the principal species of trees.

GEOLOGICAL STRUCTURE.

The drift-sheet, consisting chiefly of till, and probably varying from 100 to 200 feet in depth, covers both these counties and wholly conceals the bedrocks. Beneath the drift are doubtless in many places deposits of Cretaceous age, similar to those outcropping in Brown, Redwood, Lyon and Stearns counties; but under these, or, where they are absent, immediately underlying the drift, Archæan rocks are believed to occupy this whole district, at a depth of a few hundred feet.

A well drilled for the railroad at Herman passed through 124 feet of till, and then went 65 feet in rock. The first seven or eight feet of the rock was the fine-grained, buff, magnesian limestone, boulders of which are common throughout northwestern Minnesota. Professor Winchell thinks it probable that this portion was a compacted mass of boulders. The nearest outcrops of this rock in the direction from which the drift came, are near Winnipeg in Manitoba. The remaining 57 feet were evidently in Archæan rocks, being quartzose granite, with red feldspar; white micaceous quartzyte; and mica-schist of several varieties.

The glacial drift forming the surface of these counties has the same smoothly undulating or rolling contour which characterizes the greater part of the Minnesota basin. Its only portion presenting the rough, irregularly grouped, stony knolls and hills of terminal moraines is in northeastern Grant county, including Pelican Lake, some parts of Erdahl, and the northeast corner of Pomme de Terre. These morainic accumulations belong to the time of the eighth or Fergus Falls moraine. The ice-sheet appears to have lain upon this district until its recession from the seventh or Dovre moraine, when it was melted back from Swift and Big Stone counties to Fergus Falls and the Leaf hills in Otter Tail county.

The gravel on the bottomland of the Pomme de Terre river is about half limestone; and nearly the same proportion holds for the gravel of lake-shores and for that contained in the till. A much less proportion of the large boulders is limestone, perhaps not more than a twentieth generally, and in some localities scarcely a hundredth, the remainder being granite, syenite, gneiss and crystalline schists. But in section 31, Elk Lake, a half mile north of Gilbert Anderson's, about a dozen limestone blocks, three to eight feet in size, were seen near together one to three rods west of the road, much outnumbering the comparatively small granitic boulders that could be counted on the same space.

The valleys of the Pomme de Terre and Chippewa rivers, 50 to 100 feet deep along most of their course, and one-fourth mile to one mile or occasionally more in width, were avenues of drainage from the melting ice-fields in their northward retreat. By these glacial floods the Pomme de Terre valley was eroded below its present depth, and the subsequent alluvial deposits brought in by tributaries and washed down from adjoining bluffs by the springs in their ravines, have filled some portions higher than others, so that depressions not thus filled hold the Pomme de Terre and Little Pomme de Terre lakes and two lakes in the west part of Sahlmark.

Lake Agassiz, formed in the basin of the Red river by the barrier of the retreating ice-sheet, extended into the northwest part of Eldorado, the most northwest township of Stevens county, and its upper beach continues thence northward through Grant county, lying four to six miles east of the county line. On the area occupied by this glacial lake, the surface is notably smoothed and nearly flat. Its material here is mainly till, in some places showing indistinct marks of stratification due to the leveling action of the lake, but containing sand and gravel and frequent boulders, and much more properly classed as till than as modified drift. No lakes are now found on this part of the area that was covered by lake Agassiz, but it has occasional sloughs, sometimes a mile or more in extent. Besides the upper or Herman beach of this lake, which is crossed by the Saint Paul, Minneapolis & Manitoba railway one and a half miles northwest of Herman, its next lower or Norcross beach is well exhibited through the west range of townships of Grant county, being crossed by this railway at Norcross, five miles northwest of Herman. These beaches consist of gravel and sand, each being a low, flattened ridge, ten to twenty or hirty rods wide, three to ten feet above the adjoining land on the side away from the lake, and having a descent of ten to twenty feet on the other side.

The outlet of lake Agassiz flowed in the remarkable channel or valley which now contains lakes Traverse and Big Stone and the Minnesota river. At the time when the upper beach was formed, its mouth was about eighty feet above the present surface of lake Traverse or 1,050 feet above the sea. The Norcross beach in Grant county is one to three miles west of the upper or Herman beach and about 30 feet lower, showing that the outlet of the lake had eroded its channel considerably during the time between the stages recorded by these beach-ridges. For a discussion of the ascent of the beaches toward the north and more detailed statements of their characters and relationship, with a brief description of the general features of lake Agassiz and the area which it covered, the reader is referred to the next chapter.

The following notes were taken in connection with the work of mapping these beaches and leveling to determine their elevation.

Upper or Herman beach. This beach-ridge is well displayed in the N. W. ¼ of section 19, Eldorado, having an elevation about 1063 feet above the sea. Through section 18, it is twenty to twenty-five rods wide, with its top at 1063 to 1066 feet, being a gently rounded ridge of sand and gravel, containing pebbles up to two or three inches in diameter. Its hight is seven to ten feet above the land next west, and five feet above the depression next east. The surface on each side is till, slowly falling westward and rising eastward.

In the southeast part of section 7, Eldorado, the crest of the beach is at 1067 to 1070 feet. Here and onward the next two miles, through the N. W. ¼ of section 8, the southeast part of 5, and the western and northern part of section 4, Eldorado, this formation is finely exhibited in a ridge of gravel and sand, twenty to thirty rods wide, fifteen feet or more above the land at its base westward, where lay the glacial lake Agassiz, and eight to ten feet above the depression eastward, which divides it from the higher, moderately undulating expanse of till beyond. In the east part of section 5, its elevation is 1065 feet; and through section 4, 1065 to 1072.

Sill of Ezra S. Dunning's house, section 3, Eldorado, 1074 feet.

Water in the South branch of Mustinka river, five feet deep, in the N. W. ¼ of section 34, Logan, 1053.

Beach in the northwest part of section 27, Logan, 1067 to 1069; in the S. W. ¼ of section 22, 1067; in the north part of this section 22, and the south part of section 15, Logan, forming a broad, smoothly rounded gravel-ridge, 1068 to 1071.

Beach near the middle of section 15, Logan, a third of a mile southwest from Dr. Paquin's, about thirty rods wide, with a broad nearly flat top, 1070; having a descent of about fifteen feet on its northwest side to the area of lake Agassiz, and half as much on the southeast, thence rising very gradually in the one and a half miles eastward to Herman. This ridge is gravel; the land at each side, till.

Beach equally well exhibited, at Dr. C. O. Paquin's, at the southeast corner of section 10, and in the southwest part of section 11, Logan, 1069 to 1071; and in this section 11, at the railroad, and for fifty rods southwestward 1064 to 1066. In the cut through this beach-ridge for the railroad, its material is sand and gravel, containing pebbles up to two or three inches in diameter, half or two-thirds being limestone.

Depression forty rods wide next southeast at the railroad, lowest twenty rods from the top of the beach, 1060 to 1063.

Surface of till at the southeastern snow fences of the railroad, about a third of a mile southeast from the beach, 1073; at the northwest end of the northwestern snow-fences, about twenty-five rods northwest from the highest part of the beach, 1054; and at the 180th mile-post, about a quarter of a mile northwest from the last, 1049.

Railroad track at Herman, 1070; at the 180th mile-post, 1051.

Joseph Moses' house, floor of piazza, in the S. W. ¼ of the N. W. ¼ of section 18, Delaware, 1067; beach here, on which this house is built, 1066 to 1067.

H. D. Kendall's house, at the east side of the S. E. ¼ of section 12. Gorton, on the western slope of the beach, 1062; top of beach-ridge about twenty-five rods east of Mr. Kendall's house, 1067. Beach through the next one and a half miles north from Mr. Moses', along the west side of sections 18 and 7, Delaware, 1066 to 1068. The beach for this distance is conspicuously developed, having a width of about twenty-five rods, rising five to eight feet above the depression at its east side and ten to fifteen feet above the land west.

L. I. Baker's house, sill, in the S. W. ¼ of section 6, Delaware, of same hight with the top of the beach-ridge, on which it is built, 1068.

Beach in section 31, Elbow Lake, not so conspicuous as usual, 1066; in or near the S. W. ¼ of section 19, this township, 1070; in the S. W. ¼ of section 18, at the house of Henry Olson, a gracefully rounded, low ridge, as elsewhere, composed of gravel and sand, including pebbles up to three inches in diameter, 1065 to 1066; at Mrs. John S. Ireland's, in the N. W. ¼ of this section 18, 1070; at Dr. J. M. Tucker's, in the N. E. ¼ of the N. E. ¼ of section 2, North Ottawa, 1071; about one mile north of last, near the north side of section 35, Lawrence, 1075; and about one mile farther north, also 1075.

Beach about thirty rods west of M. L. Adams' house, in the N. E. ¼ of section 26, Lawrence, 1075 feet, being four feet above the land adjoining this ridge on the east, and about ten feet above the flat land near on the west; in section 23, Lawrence, 1076; and near the south side of section 10, 1069 to 1074.

Extensive sloughs or marshes occur in section 36, and in sections 25 and 24, Lawrence, each being about a mile long, lying on the east side of the beach-ridge at Dr. Tucker's and reaching two and a half miles northward; the elevation of these above sea-level is about 1060 feet.

In the north part of section 10, and the south part of section 3, Lawrence, the shore line of lake Agassiz is not marked, as usual, by a gravel ridge, but by a somewhat abrupt ascent or terrace, the top of which, composed partly of gravel, is 1085 to 1079; base of this terrace and land westward, consisting of till slightly modified on the area of lake Agassiz, 1060 to 1050. This escarpment, the eroded shoreline of the glacial lake, passes about forty rods west of N. S. Denton's, at the north side of section 10, Lawrence.

Beach in section 34, Western, the most southwest township of Otter Tail county, near John F. Wentworth's, 1070 to 1075.

Norcross beach. At Norcross depot this beach has the same elevation as the railroad track, 1039 feet above the sea. There is a depression three feet lower on the southeast, and the surface ten to fifteen rods northwest from the top of this beach, on the side where the lake was, is 1032 to 1034. Thence a very smooth plane descends to Gorton, Campbell, and the Red river at Breckenridge. About fifty rods northeast from Norcross depot, the beach attains its greatest hight in this vicinity, 1043 feet. It is a rounded, low ridge of sand and gravel, lying on an area of till, having the same characters as the upper beach at the numerous places where that has been described. The course of the Norcross beach has been mapped, but its elevation has not been exactly determined at other points in this county. In Western, Otter Tail county, its elevation is approximately 1045 feet.

Further notes of these beaches will be found with the records of wells in Lawrence, Gorton and Eldorado.

Wells in Grant county.

Elk Lake. G. Erdahl; on the bluff east of the Pomme de Terre river in the northwest part of the township: well, 104 feet; soil, 2; yellow till, 33; harder blue till, 30; gray till, lighter-colored, 7; dry sand, 28; and gravel and sand, containing water, 4 feet and extending lower.

Sam Olson; sec. 26, at the north side of the east end of Elk lake: well, 13 feet; soil, 2; yellow till, 5; and coarse gravel, containing pebbles up to three inches in diameter, 6 feet and reaching deeper; plenty of good water.

Ole Ring; about one and a half miles west from the west end of Elk lake: well, 74 feet; soil, 2; yellow till, very hard and dry, 33; quicksand, 1 foot, with water; and moist blue till, softer to bore than the upper till, 38 feet and continuing below; the only water, a rather scanty supply, comes from the quicksand.

Mr. Alfred Schedin, who reports these wells and others in Lien and Roseville, states that the blue till is usually harder than the overlying yellow till; often one to six feet in thickness of the blue till next above a water-bearing layer of sand and gravel, is harder, darker and more gravelly than its other portions; no fossils have been found, but fragments of lignite occur frequently in the till, the largest being about four inches in diameter.

Land. Gilbert Anderson; sec. 6: well, 18 feet, unfinished; yellow till, 14; harder blue till, 4.

Pomme de Terre. N. Q. Punches' store in the village: well, 22; soil, 1½; sand, 20½, to water. This is only ten or twelve rods from the river. Most of the wells near are in till.

Halvor Olson; sec. 24: well, 35 feet; soil, 1½; yellow till, 30; harder blue till, 3; water rose twelve feet from gravel at the bottom.

Lien. T. Nilson; N. E. ¼ of sec. 2: well, 26 feet; soil, 1½; yellow till, spaded, 18½; blue till, picked, almost as hard as stone, 6 feet and extending deeper; water seeps from the lower till.

Ole Lien; sec. 10, on the east side of Cormorant lake: well, 60 feet; soil, 2; soft yellow till, very gravelly in its lower portion, 53; and gravel and sand, 5 feet and reaching lower, from which water rose fifteen feet.

Roseville. William Boerner; in the west part of the township: well, 58 feet; soil, 2; yellow till, 23; and softer, moist and sticky blue till, 33; water rose slowly from gravel and sand at the bottom, accompanied with gas during the first twenty-four hours; in three or four days it reached its permanent level, six feet below the surface. A few pieces of decayed wood, up to three inches in length, were found at the depth of about fifty feet; and selenite (gypsum) crystals were found at many places from the depth of twenty feet to the bottom, occurring in masses up to three inches long.

Stony Brook. Ole Knutson; sec. 10: well, 83 feet, unfinished; soil, 2; yellow till, 20; sand, 6 inches, with a little water; harder blue till, 57; and sand, 3 feet, in which the boring was being continued; water in this sand rose two feet above it, but twenty-five pailfuls drained the supply.

Lawrence. G. H. Polar; S. W. ¼ of sec. 4, on the Norcross beach of lake Agassiz, which here is a low, rounded ridge, twenty to thirty rods wide, and five and ten feet, respectively, above the land adjoining on its east and west sides: well, 45 feet; soil, 1½; caving gravel and sand, 8; and till, yellow in its upper portion and blue below, 35 feet; water rose from the bottom, and stands ten to twenty feet below the surface.

G. H. Adams; near the centre of sec. 22, on the Norcross beach, here a low but distinct ridge five to seven feet above the land on its west side: well, 30 feet; soil, 2; gravel and sand, 2; yellow till, 16; dark and bluish till, soft and sticky, 8; and harder gray till, 2 feet, containing two boulders about a foot in diameter; water rose from the bottom six feet in the first night, and continued slowly rising a week till it came to a permanent level six feet below the surface. The water was of excellent quality, but when these notes were taken, one month after the well was dug, it had a somewhat disagreeable taste due to decay of the pine curbing.

C. W. Stickney; N. E. ¼ of sec. 34, on the Norcross beach, here ten to fifteen rods wide, two or three feet above a slough on its east side and five to eight feet above the land close westward: well, 33 feet; soil, 2; gravel and sand, 3; yellow till, 15; and blue till, 13, to quicksand, from which water soon rose to stand permanently about ten feet below the surface.

T. 129, *R.* 44. Nicholas Theis; N. W. ¼ of the S. E. ¼ of sec. 10: well, 30 feet; soil, 2; yellow till, spaded, but hard, 10; softer and moister blue till, 18 and continuing lower; well unfinished; the only water obtained is scanty, seeping from the lowest foot of the yellow till.

John Tripp; in the S. W. ¼ of sec. 35: well, 50 feet, dug 30 feet and bored below, in 1878; all till, yellow and blue, to quicksand at the bottom, from which water rises to the surface, and at the date of these notes, in 1881, had been flowing away in a constant stream during three years. It fills a ten-quart pail full in two minutes, the flow being thus nearly sixty barrels in twenty-four hours.

Gorton. Ole Thomson; in the northwest corner of sec. 14, on the Norcross beach, which is here broad and inconspicuous, elevated three or four feet above the depression on its east side and about five feet above the land on the west: well, 12 feet; soil, 2; caving gravel and sand, 7; and till, 3 and continuing deeper; three feet of water.

A well seen at Norcross while being dug, having a depth of 45 feet, was in yellow and blue till below the shallow sand and gravel beach; no layers of gravel or sand had been encountered in the till, and no water.

Logan. The following three wells are in Herman village:

C. A. Smith & Co.'s elevator: well, 63 feet; soil, 2; yellow till, most sandy in its upper portion, 15; harder blue till, 20; softer and sticky blue till, with seeping water, 8; again, hard blue till, 5; and again the soft dark till, with seeping water, 8; then hard till, 5 and extending lower; water, seeping from the till, becomes twenty feet deep in one and a half days. Fragments of lignite were found in this well at the depth of sixty feet.

H. Spence: well, 40 feet; soil, 2; yellow till, 9; sand, 1 foot, with plenty of water; then, blue till, harder, dug nine feet and bored below, in total, 28; containing no water. This well and the next, being left open when their depth was only twelve feet, were frozen in the winter, so that on being chopped out no water came in; and before their thawing they were deepened through the lower till.

O. C. Eaton: well, 45 feet; soil, 2; yellow till, 8; sand, 6 inches, with a good supply of water; blue till, 30; and sand and gravel, 5 feet and deeper, with water which rose ten feet.

In the railroad well at Herman, before described, fragments of lignite were found between the till and limestone, and from this point water rose to within six feet of the surface.

Wells in Stevens county.

Framnas. Lars Hegland; sec. 13: well, 54 feet; soil, 2; yellow till, so hard that it required to be picked, 28; hard yellow sand, 1 foot; soft yellow sand, 2 feet; blue till, similar in hardness with the upper till, 11; and yellowish gray sand, 10 feet and continuing lower; no water.

Christian Jacobson; sec. 14: well, 40 feet; soil, 2; hard yellow till, 30; sand, 2 feet, with a little water; and moist, but very hard and tenacious blue till, 6; water rose twelve feet from the bottom.

Hodges. Farnsworth & Newcomb; sec. 23: well, 53 feet; soil, 2; yellow till, 15; very hard gray till, 10; dark bluish till, 26; to very coarse gravel, made up of pebbles to six inches in diameter, with no sand, full of water, which rose eighteen feet in five minutes.

H. D. Tenney; S. E. ¼ of sec. 32: well, 54 feet; soil, 2; yellow till, 12; very hard bluish till, with iron-rusted portions, having a tendency to crumble on exposure to the air, 14; sticky blue till, easily bored, but when exposed to the sunshine drying to a very hard mass, 22; changing into clayey quicksand of the same dark color, with water, 3½ feet; to gravel, from which water rose twenty-five feet.

Rendsville. H. C. Parlin; sec. 2: well, 30 feet; soil, 2; yellow till, spaded, 6; harder, dark bluish till, 22 and extending lower; the only water obtained is that which seeps from the upper till.

Thomas G. Heenan; S. E. ¼ of sec. 25: about fifteen feet above a branch of a lake on the east, and some ten feet below the fertile plain with subsoil of sand which extends thence one and a half miles southward: well, 35 feet; soil, 2; yellow till, 15; and very hard dark bluish till, 18; water, struck at the bottom, rose in one and a half minutes eighteen feet, filling the boots of a man at the bottom with gravel; he narrowly escaped drowning.

Morris. Several wells in this township, and others in Hodges and Eldorado, were reported by Mr. John Richards. The following are in the village.

Well at the residences of F. B. Kenner and R. C. Moore, in the west edge of the village, 82 feet; soil, 2; yellow till, 6; dark, bluish gray till, dry and very hard, 10; softer and moister blue till, 55, containing a sandy layer one foot thick, with some water, forty-two feet below the surface; white sand, 1½ feet, yielding good water, which rose twenty feet in a half day; beyond which the boring was continued in dark bluish, very hard till, 8 feet.

Bank of Morris: well, 75 feet; soil, 2; yellow till, 15; dark, very hard till, somewhat streaked with yellow, 8; moist but quite hard blue till, very tenacious, containing boulders up to one foot in diameter, 42; sand, 8 feet; and water-washed gravel, 6 inches; water abundant, not rising.

Perkins House: well, 65 feet, about six rods southeast from the last; soil, 2; yellow till, 10, containing some water in its lower part; harder blue till, 50; and sand and fine gravel, with water, 3 feet. At the stable of this hotel a well only 13 feet deep, all in yellow till, found water which rose four feet from a vein of sand and is permanent, being a sufficient supply for twenty or thirty horses.

L. E. Pearce: well, 69 feet, bored 38 feet and driven below, in till to gravel and sand from which water was obtained. The water is considered of good quality, but is very hard. Mr. Pearce also constructed a cistern near this well, 15 feet deep, which was used a year and a half, being filled from rain on the roof, when a spring broke into the cistern through its coating of cement, and has since afforded an ample and constant supply of water.

At the steam elevator a well 66 feet deep was soil, 2; yellow till, 13; harder, but moist and very tenacious blue till, picked, 16; and sand and gravel, 35 feet, most gravelly in the last ten feet, to water at the bottom. The well at the Evans House, 72 feet deep, was nearly the same as at this elevator.

Donnelly. New Moose Island railroad-tank, on the northeast side of the lake in section 4, and about fifteen feet above it: well, 55 feet, unfinished; soil, 1½; yellow till, 6; blue till thence to quicksand at the bottom, into which the well had gone 3 feet at the time of this record.

Gen. T. H. Barrett; on the south side of this lake in sec. 4: well, 52 feet; soil, 2; yellow till, 10; dark, very hard, dry till, 12; dark bluish till, moist and very tenacious, quite hard, 27; and sand, 1 foot; from which excellent water rose twenty-five feet.

Wells in Donnelly village find plenty of water 12 to 20 feet below the surface. At the railroad section-house a well 40 feet deep was yellow till, spaded, 20; and harder blue till, picked, 20 and continuing deeper; water seeps plentifully from the base of the upper till, but none was obtained in the lower till. The well on Ignatius Donnelly's farm in sec. 31, Rendsville, a mile east from this village, is 18 feet deep, being soil, 2; and yellow till, 16; to gravel, from which water rose eight feet.

Pepperton. Michael Stahler; sec. 32: well, 17 feet; soil, 2; and yellow till, 15; water rose five feet from gravel at the bottom.

Eldorado. F. B. Kenner; S. E. ¼ of sec. 5, near the upper beach of lake Agassiz: well, 115 feet; soil, 2; gravel and yellow till, 13; dark, very hard, dry till, 10; changing to softer and sticky blue till, which grew harder in its lower part, 90 feet and extending lower; no noteworthy sand-veins were found; water seeps near the surface and scantily at the depths of 60, 85 and 115 feet.

S. C. Cook; in sec. 7, at the middle of its east side, on the upper beach of lake Agassiz: well, 100 feet; soil, 2; gravel and sand, 12; all till below to gravel at the bottom, from which water rises to a permanent level about twelve feet below the surface.

A. C. Mackenzie; N. W. ¼ of sec. 22: well, 13 feet; soil, 2; yellow till, 11; water rises about seven feet from a vein of sand.

T. 124, *R.* 44. Edward McCarty; sec. 6: well 20; yellow till, 15; dark bluish till, moist and softer, 5; well unfinished.

MATERIAL RESOURCES.

These are prairie counties, with rich soil, and agriculture is the leading occupation.

Water-powers. The Pomme de Terre mill, at Pomme de Terre village, has eleven feet head.

Johnson's mill, near the north line of section 8, Framnas, has eight feet head.

The Riverside mill, owned by H. W. Stone & Co., in the north part of section 12, Darnen, nearly two miles southeast from Morris, has eight feet head; three run of stone for flour, and one for feed.

All these are flouring mills, on the Pomme de Terre river.

Building stone. As there are no outcrops of rock, the boulders of the drift are considerably used for rough masonry. They are frequent throughout much of the district, but are comparatively scarce on the more smooth and flat areas.

Lime. Magnesian limestone boulders are burned for lime by Halvor Larson in the southwest part of Pelican Lake township, producing about a hundred barrels yearly, and selling for $1 per barrel. It is white lime of excellent quality. Lime is also burned by Peter Olson in the north part of this township, and by Jacob Olson and Gilbert Gilbertson in the northwest part of Erdahl on the southeast side of Pomme de Terre lake.

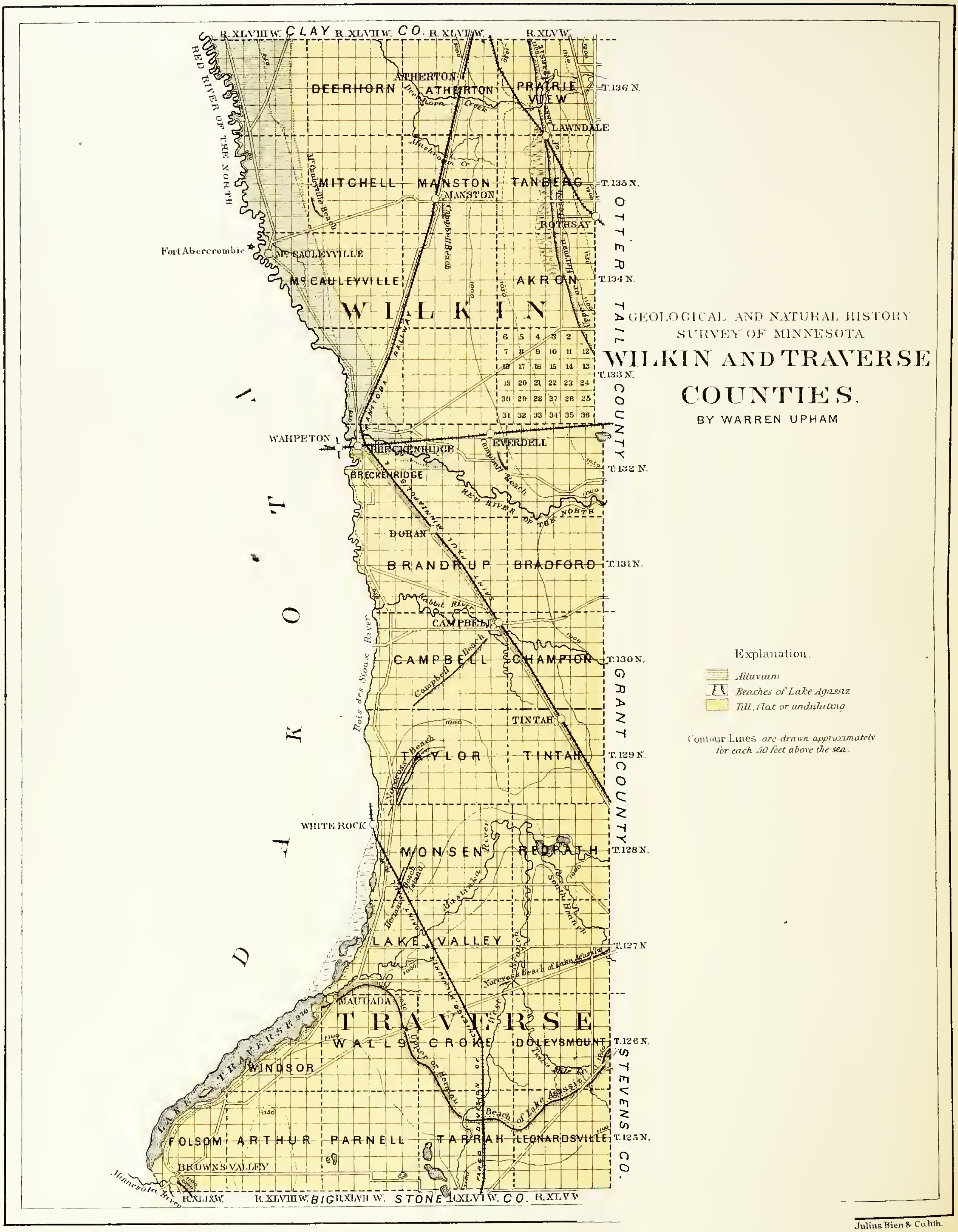
Joseph Meier at Donnelly burns 400 to 800 barrels of lime yearly, selling in this vicinity and at Morris for $1.25 per barrel. The lime of about half the boulders gathered is white, and of the others straw-colored. Mr. Meier uses maple or oak wood, which costs about $5 per cord, six or seven cords being required for a kiln of a hundred barrels.

Bricks. The first brick-making in these counties was begun in 1881, by Collins and O'Laughlin, working for Kemmer & Moore; product that year, 400,000, selling for $10.50 per thousand. The clay used is till, excavated to a depth of five or six feet, containing gravel, a large part of which is limestone, so that nearly every brick is more or less cracked by the slacking of particles of lime. Some sand, hauled from the Pomme de Terre river, is mixed with this clay for tempering. The bricks are mostly cream-colored, but have a notably greenish tint where they are subjected to the greatest heat, and a light pinkish color close to the outside of the kiln, where the heat is least.

ABORIGINAL EARTHWORKS.

An artificial mound of the usual dome-like form, forty feet across and six feet high, lies in section 12, Lien, about thirty rods east of the road and a half mile southwest from Little Pomme de Terre lake, which is about 75 feet lower.

Another mound, about five feet high, was seen a half mile north-northwest from the old Moose Island tank, on land some 20 feet above a little lake close east. This is four miles southeast from Herman.



Julius Bien & Co. lith.

CHAPTER XIX.

THE GEOLOGY OF WILKIN AND TRAVERSE COUNTIES.

BY WARREN UPHAM.

Situation and area. Wilkin and Traverse counties (plate 50) adjoin the west boundary of Minnesota, which is here made by the Red and Bois des Sioux rivers and lake Traverse. Breckenridge, the largest town and county seat of Wilkin county, is about 190 miles distant (in a direct line) northwest from Saint Paul and Minneapolis. Brown's Valley, the largest town and county seat of Traverse county, situated on the Minnesota river a mile southeast from the head of lake Traverse, is 47 miles south from Breckenridge. Other important towns and villages are McCauleyville on the Red river, and Manston and Campbell on the Saint Paul, Minneapolis & Manitoba railway, in Wilkin county; and Tintah on this railway in Traverse county.

Wilkin county extends 42 miles from north to south, and its width varies from 24 to 14 miles, decreasing toward the south. Its area is 751.04 square miles, or 480,664.88 acres, of which 4,277.12 acres are covered by water.

The length of Traverse county from north to south is 30 miles, and its width varies from 15 to nearly 29 miles, increasing toward the south. Its area is 581.83 square miles, or 372,369.46 acres, of which 8,906.00 acres are covered by water.

SURFACE FEATURES.

Natural drainage. These counties are wholly included within the basin of the Red river of the North, excepting a few square miles in the southwest corner of Traverse, which are drained by the Minnesota river. The Red river, a large stream flowing from the many lakes of Becker and Otter Tail counties, crosses Wilkin county in a westerly course to Breckenridge, where it bends sharply to a northward course. South from Breckenridge, the line in continuation of the lower part of the Red river is marked by the Bois des Sioux river, a small and sluggish stream during the dry season, filled with rushes and aquatic grasses, the outlet of lake Traverse. Rabbit river, which drains the south end of Wilkin county, joins the Bois des Sioux ten miles south of Breckenridge.

Lake Traverse is fifteen miles long, and from one to one and a half miles wide; it is mostly less than ten feet deep, and its greatest depth probably does not reach twenty feet. The Mustinka river, which drains the greater part of Traverse county, enters the northeast end or foot of this lake. On most maps, however, lake Traverse is extended eight or ten miles farther north, to include a tract of marsh one to three miles wide, in which are numerous spaces of open water a mile or two in length.

Several lakelets, a quarter of a mile to one mile long, occur in southern Wilkin county; and probably some of small size lie in the east part of Prairie View, Tanberg and Akron, on the east border of Wilkin county. More than half of Traverse county, and all of Wilkin county, excepting the portions of the three townships named, were covered by the glacial lake Agassiz during the recession of the ice-sheet, and the leveling action of that lake so smoothed the drift surface on this area that it has only one lakelet, this being about a half mile in diameter at the southeast corner of section 1, T. 132, R. 45. Sloughs, however, are frequent on this area and occasionally extend three to five miles in a continuous, impassable marsh, rarely with permanent spaces of open water, oftener with spots where water remains all summer but is filled by tall reeds, rushes and grasses. Such sloughs occupy a width of about a mile and a length of ten miles from north to south along the west side of the upper beach of lake Agassiz in Tanberg and Akron.

Topography. The east portions of Prairie View, Tanberg and Akron, which are the highest land of Wilkin county, have a moderately undulating or rolling surface, with elevations 10 to 40 feet above the depressions; and the same description is also applicable to the southern tier of townships in Traverse county, and to Windsor and Walls, reaching north to the mouth of Mustinka river, these being also the highest land of Traverse county. The remainder of this district lies within the area of lake Agassiz and is distinguished by a more smoothly undulating contour, having in some parts an almost perfectly flat surface. From the east border of lake Agassiz a gentle slope falls toward the west and northwest to the Bois des Sioux and Red rivers on the state boundary; excepting in northwestern Traverse county, where a swell of land 60 to 80 feet in hight lies within this area in the west part of Taylor and Monsen. The Bois des Sioux and Red rivers have cut a channel 20 to 40 feet deep along the axial depression of the lacustrine plain, to which the river-banks usually rise steeply on one side and by moderate slopes on the other, enclosing only few and narrow areas of bottomland.

On each side of lake Traverse bluffs rise steeply 100 to 150 feet, having their greatest hight along the southwest or upper part of the lake, and continue 125 to 150 feet high on each side of Brown's Valley, five miles long, between this and Big Stone lake, and along the whole extent of the latter lake, which is twenty-six miles long. Thus these lakes lie in a continuous valley one and a half to two miles wide, excavated 125 to 150 feet deep in the sheet of glacial drift, which has an undulating or rolling contour of the same average elevation as the top of the bluffs enclosing the lakes. Farther southeast this remarkable valley is occupied by the Minnesota river. The hight of lake Traverse is 970 feet above the sea; the divide in Brown's Valley, a mile southeast from the head of this lake, on the water-shed between the Red and Minnesota rivers, is only three feet higher, or 973 feet above the sea-level; and the hight of Big Stone lake is 962 feet.

Elevations, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

a. *Fergus Falls line.*

	Miles from Saint Paul.	Feet above the sea.
Rothsay -	204.0	1188
Water-tank, sec. 33, Prairie View, grade	210.0	1088
Top of bank of gravel and sand, upper beach of lake Agassiz, excavated for ballast along a spur track extending a third of a mile north from the tank - - -	210.0	1091 to 1094

b. *Breckenridge line.*

	Miles from Saint Paul.	Feet above the sea.
Tintah	194.60	995
Rabbit river, grade -	201.00	982
Campbell	201.68	982
Doran -	208.88	971
Breckenridge	216.25	959
Red river of the North, water - - - -	216.85	943

c. *Breckenridge to Barnesville.*

	Miles from Saint Paul.	Feet above the sea.
Breckenridge	216.25	959
Red river, water, 949; grade	217.2	963
Manston	232.5	976
Mushroom creek, water, 972; grade	235.5	979
Deer Horn creek, water, 970; grade	239.2	980
Atherton	239.3	979
Barnesville	245.0	1018

d. *Brown's Valley branch.*

	Miles from Saint Paul.	Feet above the sea.
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

Elevations, Fergus Falls & Black Hills division, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, Saint Paul.

	Miles from Wadena.	Feet above the sea.
Ames	60.10	1063
Everdell	67.89	992
Red river, bottom, 954; grade	74.09	969
Breckenridge	76.45	960
Bois des Sioux river, bottom, 944; grade	76.71	960
Wahpeton	77.47	963

The following determinations of the elevation of the Red river are from leveling by the writer, by railroad surveys, and by the United States engineer corps under the direction of Capt. C. J. Allen.

Red river of the North, ordinary low water.

	Feet above the sea.
On the east line of Wilkin county	1000
At railroad bridge 2⅓ miles east of Breckenridge	956
Mouth of Bois des Sioux river, at Breckenridge and Wahpeton (highest floods here, about 958)	943
At McCauleyville and Fort Abercrombie (highest floods here, about 934)	909
At the northwest corner of Wilkin county	885

The extreme elevations of Wilkin county are 1,200 to 1,250 feet in the east part of Prairie View and Tanberg, and 885 feet where the Red river crosses the line between this and Clay county. The average hights of the townships are estimated as follows: Prairie View, 1,110 feet above the sea; Tanberg, 1,110; Akron, 1,080; T. 133, R. 45, 1,050; T. 132, R. 45, 1,030; Bradford, 1,010; Champion, 995; Atherton, 980; Manston, 1,000; T. 134, R. 46, 1,010; T. 133, R. 46, 1,000; T. 132, R. 46, 980; Brandrup, 975; Campbell, 980; Deerhorn, 950; Mitchell, 970; T. 136, R. 48, 930; T. 135, R. 48, 940; McCauleyville, 965; T. 133, R. 47, 960; and Breckenridge, 965. The mean elevation of Wilkin county derived from these figures is 1,000 feet, within a fraction of a foot.

In Traverse county the extremes of elevation are a prominently rolling tract, 50 to 75 feet above the general level and three or four miles across, in the south part of Arthur, 1,150 to 1,175 feet, and lake Traverse and the Bois des Sioux river, 970 to 965 feet above the sea. Lake Traverse fluctuates about five feet, approximately from 968 to 973; and the marshes, lakes and sloughs which form the Bois des Sioux river west of Traverse county, have only a slight descent, probably to 965 feet at the lowest stage of water on the line between these counties. Estimates of the average hights of the townships are as follows: Tintah, 1,000 feet; Redpath, 1,010; T. 127, R. 45, 1,025; Doleysmount, 1,045; Leonardsville, 1,080; Taylor, 1,000; Monsen, 1,020; Lake Valley, 1,015; Croke, 1,040; Tarrah, 1,075; Walls, 1,075; Parnell, 1,110; Windsor, 1,075; Arthur, 1,125; and Folsom, 1,075. The mean elevation of Traverse county, derived from these figures, is approximately 1,045 feet above the sea.

Soil and timber. This district is the southern end of the fertile Red river valley, far famed for the large harvests and superior quality of its wheat. Besides this chief export, it is well adapted for stock and dairy farming, and for all the various crops and garden fruits and vegetables of this latitude.

Timber occurs in groves on the bluffs of lake Traverse, but not in any noteworthy amount elsewhere in Traverse county. It is more abundant and larger on the southeast than on the northwest bluffs of this lake. Bois des Sioux river derives its name from the woods by which it is bordered along its lowest five miles, next to Breckenridge and Wahpeton. The Red river has no timber, or very little, for twenty miles east from Breckenridge. In the ten miles next below Breckenridge, it is bordered by scattered groves of bur-oak, green ash, box-elder, white and slippery elm, hackberry, and basswood, occupying perhaps one-fourth of this distance, while small poplars and willows occasionally appear in the spaces between the groves. Farther to the north this river is continuously fringed with timber. Nearly the whole of both these counties is prairie or natural grassland, with no trees nor shrubs, beautified in summer by a profusion of flowers, bearing a rich growth of native grass valuable for pasturage and hay, and ready for the breaking-plow, the seeder and harvester.

GEOLOGICAL STRUCTURE.

Glacial drift, probably varying from 100 to 300 feet in thickness, covers this district and conceals the underlying formations, the highest of which are supposed to be Cretaceous, as strata of that age outcrop on the Dakota side of Brown's Valley near the head of Big Stone lake and were encountered at the depth of 220 feet in a well at Fargo. The drift upon these counties is till or boulder-clay, smoothed and in part, especially in depressions, imperfectly stratified within the area of lake Agassiz.* At the time of the fifth, sixth and seventh, or Elysian, Waconia and Dovre moraines, the southwest border of the Minnesota lobe of the ice-sheet probably crossed southwestern Traverse county. To these moraines are referred the knolly and remarkably stony bluffs of lake Traverse in Folsom, within three or four miles northeast from the village of Brown's Valley, and the rolling tract of high land in Arthur. The continuation of the ice-front extended northwestward across the present place of lake Traverse, until its recession to the Dovre moraine, which may be represented by the high land in Monsen and Taylor between the Mustinka and Bois des Sioux rivers. By the next recession of the ice-sheet, to the eighth or Fergus Falls moraine, both these counties were uncovered from ice, but most of their area was instead occupied by a lake, held by the retreating ice-barrier on the north.

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* The few large boulders, three to five feet or sometimes more in diameter, which are found jutting above the surface in these and other counties of western Minnesota, are usually surrounded to a distance of five or ten feet from them by a slight hollow, about a foot below the general surface, but there is no perceptible ridge outside the hollow. This feature is doubtless due to the pawing of buffaloes in former years, while rubbing upon these boulders, the clayey dust loosened in this manner having been blown away by the winds.

Mr. Pierre Bottineau, a very experienced and observing voyageur and guide, still living at Red Lake Falls, attributes the polished surface of portions of such projecting boulders, and of ledges of rock as in Pipestone and Rock counties, to rasping by the hair and horns of buffaloes, in this way; which seems most probable, rather than that this polishing was done by wind-blown particles of sand and dust. (See vol. I, pages 63, 66 and 541. Catlin's descriptions make it certain that the polished rock-surfaces in the vicinity of the Pipestone quarry were much more noticeable in his time than now.) Similar observations and explanations are recorded by Dr. George M. Dawson in the region of the Bow and Belly rivers east of the Rocky mountains in British America, where he states that "all the larger boulders of the district are surrounded by a shallow saucer-like depression, caused by the pawing of the buffalo, and their angles are worn quite smooth and glossy by the rubbing of these animals upon them." (*Report of Progress of the Geological Survey of Canada*, 1882-84, p. 149C.)

Another notable feature ascribed to buffaloes is the very rough surface often found on areas of slightly moist land in the Red river valley, the ground being indented by many hollows and holes five to twenty feet across and one to five feet deep with steep sides. These are commonly called "buffalo wallows."

When this part of the state was examined in 1881, the disappearance of these animals was so recent that their bones, especially their skulls, were frequently seen on the prairie. In many places, also, rings of taller and greener grass than the ordinary prairie sward were observed, having a width of five or six feet, and forming a circle from two to six rods in diameter. According to Mr. James Nolan of McCauleyville, these mark a circuit tramped by buffalo cows while walking around their calves at night to guard them from besieging wolves. Occasionally a half-circle of such grass was seen, and this was said by Mr. Nolan to be where a lone buffalo guarded her calf from a lone wolf which staid on one side through the night, while the buffalo walked back and forth in this half-circle.

[Bearing directly on the question of the origin of these polished surfaces are the following additional facts: (a) In 1873 the writer examined an immense boulder lying in the bottomlands of the Chippewa river near Montevideo in Chippewa county. It consists of coarse-grained red granite and its horizontal extent is 35 feet. It rises 25 feet above the surrounding prairie. The very top of this boulder, where no buffalo could have "rubbed" it, is finely polished in a manner similar to that seen on the quartzyte. The sides of this boulder are not thus polished, but are granular and crumbling. (b) Where this polishing is found in southwestern Minnesota it sometimes extends over many square rods of nearly horizontal surface, and it prevails on the inaccessible cliffs and projections. It seems very strange if buffaloes could thus have polished it by "rubbing." (c) In the area of the original Huronian, north of lake Huron, are extensive ranges of the same quartzyte, on which no timber grows, from lack of soil. The writer saw similar polished surfaces there in July, 1887. No record has been preserved of the running of buffaloes so far from their well-known prairie haunts. The all-efficient cause of this polishing is believed to have been the dust and sand particles that fly with the wind.—N. H. W.]

Lake Agassiz. During the retreat of the ice from lake Traverse to Hudson bay, free drainage could not take place, because the descent of the land is northward. As soon as the border of the ice had receded beyond the watershed dividing the basin of the Minnesota from that of the Red river, it is evident that a lake, fed by the glacial melting, stood at the foot of the ice-fields, and extended northward as they withdrew along the valley of the Red river to lake Winnipeg, filling this valley and its branches to the hight of the lowest point over which an outlet could be found. Until the ice-barrier was melted upon the area now crossed by the Nelson river, thereby draining this glacial lake, its outlet was along the present course of the Minnesota river. At first its overflow was upon the nearly level, gently undulating surface of the drift, about 1,100 feet above the sea, at the west side of Traverse and Big Stone counties; but in process of time this cut a channel here 125 to 150 feet deep, and from one to two miles wide, in which lie Traverse and Big Stone lakes, respectively 970 and 962 feet above the sea. From this outlet the plain of the Red river valley, 30 to 50 miles wide, stretches 315 miles north to lake Winnipeg, which is 710 feet above the sea. Along this entire distance there is a very uniform continuous descent of a little less than one foot per mile. The drift contained in the ice-sheet upon this area, and the silt gathered by its glacial rivers, were here deposited in a lake, shallow near its mouth, but becoming gradually deeper northward. Beyond our international boundary this lake covered a large area, varying from 100 to 200 miles in breadth at and west of lake Winnipeg; and its total length appears to have been at least 600 miles. Because of its relation to the retreating continental ice-sheet, this lake has been named in memory of professor Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land-ice.

A large part of the shore-line of this ancient lake was traced, and its hight determined, in the summer of 1881. Horace V. Winchell was my efficient assistant as rod-man in the work of leveling, by which the hight of the upper beach was ascertained along its whole extent examined. This was about 175 miles, following the course of the old shore, extending from lake Traverse to the north side of Maple lake, twenty miles east of Crookston. The distance that it includes from south to north is 142 miles.

Along nearly the whole of this distance there exists a remarkable deposit of beach gravel and sand, forming a continuous, smoothly rounded ridge, such as is found along any part of the shores of the ocean or of our great lakes where the land sinks in a gently descending slope beneath the water-level. Usually the beach of lake Agassiz is a ridge three to ten feet above the land next to it on the side that was away from the lake, and ten to twenty feet above the land adjoining it on the side where the lake lay. In breadth this beach-ridge varies from ten to twenty-five or thirty rods. It is thus a broad wave-like swell, with a smooth, gracefully rounded surface.

Such being a section across the beach, it is to be remembered that this ridge extends along the whole distance that was explored, with only here and there gaps where it has been cut through by streams and rare intervals of a quarter or a half mile or at the longest two or three miles where the outline of the lake-shore, or the direction of the shore-currents, prevented such accumulation. There are similar interruptions in the beaches of present lakes and on the sea-coast; and like these modern deposits the beach of lake Agassiz varies considerably in its size, having in any distance of five miles some portions five or ten feet higher than others, due to the unequal power of waves and currents at these parts of the shore. The moderate slope of the land toward lake Agassiz was favorable for the formation of a beach-ridge, and it has been clearly traced as one continuous formation along this distance of 175 miles. In calling it continuous, my meaning is that whenever it is interrupted it is found a little distance farther along, beginning again at very closely the same hight.

The gaps where the beach is not a distinctly traceable ridge-like deposit of gravel and sand, cannot exceed one-twentieth of its whole course. In a few places the lake has undermined its shore, forming a terrace in the till, with no definite beach-deposit, the work of the waves having been to erode and carry away rather than to accumulate. In other places, sometimes two or three miles in length, the area where this ancient lake had its margin is a marsh or shaking bog, full of spring water, and rough with hummocks of grass.

Nearly everywhere along the course of this beach of lake Agassiz the land on each side is till, or unstratified clay, containing some intermixture of sand and gravel, and occasional stones and boulders. The material of the beach-ridge is remarkably in contrast with this adjoining and underlying till, for it includes no clay but consists of stratified sand and gravel, the largest pebbles being usually from two or three to six inches in diameter. It is a very significant fact that no boulders were observed anywhere in or on any of the beach-deposits of this lake.

When lake Agassiz stood at its greatest hight and formed the upper beach, its outlet was about 80 feet above the present surface of lake Traverse, or 1,050 feet above the sea. The channel which at this time had been excavated in the drift by its outflow was 30 to 50 feet deep along the distance of about fifty miles where now are lake Traverse, Brown's Valley, and Big Stone lake. This *upper or Herman beach* is crossed by the Breckenridge line of the Saint Paul, Minneapolis & Manitoba railway at a point about one and a half miles northwest from Herman.

Three lower beaches, of the same character as to form, size and material, with the highest, were also noted; their course was traced through long distances; and their hight was determined by our leveling. At the next epoch, after that of the upper or Herman beach, when the lake-level was again nearly stationary long enough to form a ridge of gravel and sand upon its shore, the outlet had been eroded about 25 feet deeper than at the time of the upper beach, but was still 55 feet above the present lake Traverse and Brown's Valley. The beach of lake Agassiz when it had this lower level is crossed by the Breckenridge railway line at Norcross, five miles northwest of Herman. This is accordingly named the *Norcross beach.* Its course and hight have been determined through an extent of a hundred and fifty miles from Norcross northward to a point twenty-five miles north of Maple lake and ten miles beyond Red Lake Falls.

A third series of beach-deposits was formed when the outlet had been lowered some 50 feet more, to 975 feet above the sea. The beach of this third stage of lake Agassiz crosses the township of Campbell in southern Wilkin county from southwest to northeast, and hence it is denominated the *Campbell beach.* The course of this formation through Wilkin and Clay counties has been noted at a few places, and is thus known approximately. Through its next eighty miles, from the Wild Rice river to Middle river, it has been traced continuously.

The fourth and lowest beach of lake Agassiz while it outflowed to the south, was formed after a further erosion of 15 feet, lowering the outlet to 960 feet above the sea, and completing the excavation of its channel to the present beds of Traverse and Big Stone lakes. My first observation of this beach was in section 30, Mitchell, three and a half miles northeast from McCauleyville, and it is therefore named the *McCauleyville beach.* Like the preceding, its course has not been mapped in Wilkin and Clay counties, though it has been observed and its hight determined in a few places; but farther north it has been explored along an extent of about a hundred miles, to the north line of Marshall county, sixty miles beyond Maple Lake. For forty miles next beyond Red Lake river the old Pembina trail lies most of the way upon this beach.

Four distinct series of beach-ridges of gravel and sand were thus formed by lake Agassiz at successive stages of hight during its process of deepening the channel by which it outflowed southward.

The till upon each side of lake Agassiz has a moderately undulating and rolling surface. Within the area that was covered by this lake it has a much smoother and more even contour, but has been only slightly stratified. The action of its waves gathered from this deposit of till, which was the lake-bed, the gravel and sand of its beaches; and corresponding deposits of stratified clay, derived from the same erosion of the till, sank in the deeper part of the lake. But these sediments were evidently of small amount, and are not noticeable upon the greater part of this lacustrine area, which consists of a smoothed sheet of till. The position of the thick beds of stratified fine silt and clay in the central depression of the Red river valley, shows that they were not deposited by the waters of lake Agassiz, which must have spread them more generally over its entire area; but instead proves that they were brought by the rivers which flowed into this hollow and along it northward after the glacial lake Agassiz had been reduced to its present representative, lake Winnipeg. The occurrence of shells and remains of vegetation in these stratified beds at McCauleyville 32 and 45 feet below the surface, or about 7 and 20 feet below the level of the river, as described in the records of wells on a following page, and numerous other observations of remains of vegetation elsewhere along the Red river valley in these beds, demonstrate that the valley was a land surface subject to overflow by the river at its stages of flood when they were deposited. Even at the present time much of the area of stratified clay is covered by the highest floods, and probably no portion of these stratified deposits is more than ten feet above the high-water line of the Red river and its tributaries.

The excavation of the remarkable valley occupied by the Minnesota river was first explained in 1868 by general G. K. Warren, who attributed it to the outflow from this ancient lake that filled the basin of the Red river and lake Winnipeg. He made a careful survey of this valley from lake Traverse to its mouth, and his maps and description, with the accompanying discussion of geologic questions, are a most valuable contribution to science. After his death, in recognition of this work, the glacial river that was the outlet of lake Agassiz has been named *River Warren* (vol. 1, page 622). General Warren observed that lake Traverse is 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 and Lac qui Parle are similarly due to the deposits of stratified sand and silt which the Whetstone and Lac qui Parle rivers have spread across the valley below them.

The northern barrier by which the water of lake Agassiz was restrained from flowing in the direction of the present drainage, to Hudson bay, was supposed by general Warren to have been an elevation of the land much above its present hight northeast of lake Winnipeg. He thought that this elevation was shared by other northern portions of North America, and that these regions have recently been depressed at least several hundred feet. The depths of the great lakes, and many topographic features of the interior of the continent, besides this channel of lakes Traverse and Big Stone and the Minnesota river, appeared to him to support this opinion. Instead of this, my belief is that the surface of the continent had nearly the same form then as now, and that the continental ice-sheet, resting on the land in a solid mass of great depth, formed the northern shore of lake Agassiz and was the barrier that prevented its flowing into Hudson bay.

Before adducing the evidence, apparently amounting to positive proof, of this glacial origin of lake Agassiz, which is drawn from the exploration of its beaches and determination of their hight, it ought to be mentioned that professor Dana's and general Warren's theory of an elevation of the northern part of the continent, during the ice-age or since that time, followed by subsidence to its present hight, is opposed and disproved by the general occurrence of sea-beaches and marine shells above the present sea-level all along our northern shores. They show that the ocean in these recent epochs covered more of the land than now in northern latitudes; that is, that the elevation of the land, as compared with the sea-level, was less instead of greater than at present. More than this, the hight at which these recent marine deposits and sea-shells are found, increases from south to north. In New Hampshire and Maine it is from 50 to 300 feet above our present sea-level; in the St. Lawrence valley, about 600 feet; and on the coast of Labrador, about Hudson bay, and in Greenland, 600 to 1,500 feet. The proof that the ice-sheet was the northern barrier of lake Agassiz, also gives us an answer to the question why the sea-level thus rose higher than now toward the north.

The four series of beach deposits before described, which mark the shores of lake Agassiz at as many stages of its hight, have each been examined, and their altitude determined, through an extent of about 150 miles from south to north; and each of them, like the old sea-level, is found to have a gradual ascent northward, as compared with the present level-line, or the surface which a body of water would have now, if confined in this valley. As before stated, these beaches were formed at epochs when the lake-level was nearly stationary for a considerable time during the excavation of its channel of outlet at lake Traverse and southward. The hight of the mouth of the lake and its outflowing river was at the time of the upper or Herman beach 80 feet above lake Traverse; at the time of the Norcross beach this outlet had been lowered 25 feet; when the Campbell beach was formed, it had been lowered 50 feet more, nearly to the present level of lake Traverse; and at the time of the McCauleyville beach the mouth of lake Agassiz was about ten feet lower than lake Traverse, and the bed of the outflowing river Warren was the present bottom of Traverse and Big Stone lakes.

The exploration and leveling along the upper or Herman beach extended from the north end of lake Traverse about 25 miles eastward to Herman and thence about 140 miles north to Maple lake. Through this distance it lies from fifteen to thirty miles east of the Red river. The ascent of this beach northward increases from four-tenths to three-fourths of a foot per mile in its southern portion for about 60 miles, lying in Traverse, Stevens, Grant, Otter Tail and Wilkin counties. Farther north, through its remaining 80 miles in Clay, Norman and Polk counties, its rate of ascent is considerably greater, varying from three-fourths of a foot to one and a half feet per mile. In all, the surface of lake Agassiz at this time of its greatest hight ascended northward, above a line now level, 125 feet in these 142 miles, from 1,050 feet, very nearly, above the sea in Traverse county, to 1,175 feet, very nearly, at the north side of Maple lake, twenty miles east-southeast from Crookston. Through this distance the upper beach clearly marks one continuous shore-line; and the accuracy of our leveling is attested by close agreement with railroad surveys at five widely separated points.

Before lake Agassiz had fallen below the line of this upper beach in the south half of its explored extent, it had formed a slightly lower parallel beach, three-fourths to one and a half miles distant, through the northern third of Clay county; and this secondary beach, sometimes double or treble, was noted at several places along the next thirty miles northward. The continuation of this beach at the northwest side of Maple lake was accumulated when lake Agassiz had fallen at this latitude about fifteen feet below its highest line. Here it is the second of a series of four well-defined beach ridges below the upper or first beach, which were formed when the lake had fallen successively about 8, 15, 30 and 45 feet from its highest level. Yet all these beaches were accumulated while the lake remained with only very slight depression of level, not sufficient for the formation of any secondary beach-ridge, along its southern part for some 75 miles northward from lake Traverse and Herman.

The Norcross beach has been explored and its hight measured through a length of 150 miles. In this distance it ascends northward about 70 feet by a slope that rises somewhat faster in its northern than in its southern portion, averaging a little less than a half foot per mile. The amount that the surface of lake Agassiz had fallen at this time from its highest level was 25 to 30 feet in Traverse and Grant counties, 50 feet in northern Clay county, and 85 feet northwest of Maple lake. Its fall in this extent of 150 miles had been thus 60 feet more at the north than at the south end. Double and multiple ridges occur along the northern half of this distance, and show that the lake-level at the time of formation of the Norcross beach fell five to ten feet northward while it remained without change or with less change than was required to form additional beach-ridges southward.

The hight of the Campbell and McCauleyville beaches is known along the same distance of 150 miles, in which the northward ascent of the Campbell beach is 45 feet, and of the McCauleyville beach 30 feet. The fall of lake Agassiz from the upper or Herman beach to the McCauleyville beach was 90 feet at its mouth and 185 feet at the north near Maple lake; and instead of the northward ascent of the upper beach 125 feet in 142 miles, this had been gradually diminished to 117, 110, 95, 80, 65, 55, 45, and finally 30 feet at the time of the formation of the McCauleyville beach.

If the barrier north of lake Agassiz had been land, its subsidence to give way for drainage northward in its present course would cause the beach deposits of the former lake-shores to have the opposite slope, or a descent, from south to north. These observations are therefore inconsistent with such explanation of the cause of this lake; but they appear to prove that its northern barrier was the receding continental glacier. All the differences of the once level lines of lake Agassiz from our present level-line would be produced by the gravitation of the water of the lake toward this ice-sheet. At first this attraction had a large effect upon the lake-level because of the nearness of a great depth of ice on the east in northern Minnesota and northward in British America, but it was gradually diminished to a comparatively small influence when these ice-masses had been melted and the attracting force proceeded from the region far north between lake Winnipeg and Hudson bay.

In the same way the ocean during the glacial period was drawn toward the ice-sheet, so that northward it stood higher than now, as shown by its recent deposits along our northern coasts, far above the present sea-shore. It appears that the form of the surface of the continent during the ice age was about the same as it is to-day; but that the sea-level was much changed by the great accumulations of ice, being drawn toward them by gravitation and thus raised higher than now toward the poles, while it was proportionately lowered about the equator.

The upper beach of lake Agassiz, as here described from lake Traverse and Herman north to Maple lake, extends through a prairie region, very favorable for exploration and leveling. Its farther course turns to the east and northeast and lies in a trackless forest, much of which consists of almost impassable tamarack swamps. It is therefore quite impracticable to trace its course exactly through this wilderness; but from the known elevation of Red lake, 1,125 feet, very nearly, above the sea, of the lake of the Woods, 1,042, and of Rainy lake, about 1,175, the outline of lake Agassiz when it had its greatest hight can be mapped approximately.

From the north side of Maple lake it first extends east sixty miles, passing south of Red lake. Next the shore of lake Agassiz turns northward east of Red lake, beyond which it again runs eastward, crossing the Big fork of Rainy Lake river, and extends along the south side of Rainy lake, its hight above Red and Rainy lakes being about 100 feet. Thus lake Agassiz at this time of greatest hight reached along our northern boundary beyond the meridians of Minneapolis and Saint Paul. Its expanse included no islands, excepting rarely one of small area close to its shore.

When this glacial lake attained its greatest extent, it probably exceeded lake Superior, both in length and in area. At the time of the formation of its highest beach, the depth of lake Agassiz above the lake of the Woods was some 200 feet; above the Red river valley at our northern boundary, 450 feet; and above lake Winnipeg, about 700 feet.

Detailed notes of the survey and determinations of the elevation of the beaches of lake Agassiz in these counties are as follows.

Lake Traverse, ordinary stage of water, 970 feet above the sea. Bottom of channel in Brown's Valley at the lowest point of the water-shed, 973 feet. This is three or four feet below the general surface of the valley, close to the base of the eastern bluff, about one mile southeastward from the south end of lake Traverse and a third of a mile north from Brown's Valley passenger depot. When the Minnesota river is at its highest flood in spring, a part of its water, overflowing its banks between the western bluff of the valley and this point, goes northward into lake Traverse. At such times of freshet the water in the channel at the base of the eastern bluff becomes three or four feet deep; but probably no outflow passes southward from lake Traverse into Big Stone lake.

Upper or Herman beach. Bluff east of lake Traverse, within one to two miles south from the Mustinka river, 1072 to 1075 feet above the sea; bluffs opposite these and for three or four miles northward, on the west side of lake Traverse, 1090 to 1070.

Beach-ridge forming the summit of the high land between the Mustinka and Bois des Sioux rivers, from section 35 to section 13 in the west part of Monsen, about 1050 feet. This was a shoal nearly at the lake-level during the time of the upper or Herman beach, and an island during the lower stages of the lake.

Beach in sections 2 and 11, Walls, 1060 to 1062, four to five miles east from the north end of lake Traverse, where the steep, eroded bluff gives place to the gentle slope of the natural surface, allowing the accumulation of a distinct beach-ridge of gravel. This is mostly rounded, fifteen to twenty rods in width bounded eastward, on the side toward the ancient lake, by a moderately steep slope, which descends ten or twelve feet. The land one to four miles distant northeastward, within the area that was covered by the lake, is twenty to forty feet below this beach. On the other side this ridge is succeeded by a slight depression, two to five feet deep, beyond which the land soon rises ten to fifteen feet above the beach. The material of the beach is sand and gravel, containing pebbles up to two or three inches in diameter, but all the surface elsewhere on each side is till.

Beach in sections 30 and 32, Croke, passing southeastward near the southeast corner of section 30, 1066 to 1067.

Beach near the middle of section 9, Tarrah, 1057. Its contour and material, and those of the adjoining areas, are nearly the same as at the locality already described. The width of the gravel beach here is twenty-five or thirty rods; the smoothed surface of till which descends thence northward is ten to twenty feet lower in its first mile; on the south the sheet of till is at first for forty or fifty rods about five feet lower than the top of the beach, but beyond this it gradually rises to a hight ten to twenty-five and fifty feet above the beach. The average hight of its moderately undulating surface six miles to the south at Graceville is nearly represented by the railroad at the depot there, 1107 feet.

Beach at Denis W. O'Brien's, in the S. W. ¼ of section 11, Tarrah, 1061 to 1062½. Northward from Mr. O'Brien's, as far as the view reaches, across Croke and Doleysmount, lake Agassiz was very shallow, the smooth and nearly level surface of till being 1045 to 1035 feet above the sea. For the next three miles eastward the beach is less conspicuous than usual. In the northwest part of section 8, the S. E. ¼ of 5, and through the middle of 4, Leonardville, this shore-line is again distinctly marked, but by a slight terrace descending northward in a moderately steep slope five to ten feet, rather than by the usual accumulation of gravel. The top of this terrace is at 1056 to 1057 feet. The house of Patrick Leonard is built on the edge of the terrace at the middle of the east side of section 4, Leonardsville.

In the S. E. ¼ of section 24, Doleysmount, the beach is a low gravel ridge, twenty rods wide and five feet high, having an elevation of 1060 to 1061 feet.

These determinations indicate that the surface of lake Agassiz in Traverse county was quite nearly 1045 to 1055 feet above our present sea-level.

From section 24, Doleysmount, north to sections 12 and 1, T. 133, R. 45, in Wilkin county, a distance of forty-four miles, the upper beach of lake Agassiz lies in Stevens, Grant and Otter Tail counties, east of the boundaries of this district. Where it enters Wilkin county, six miles north of the parallel of Breckenridge, the hight of the lake was about 1070 feet.

Beach near the line between Otter Tail and Wilkin counties at the east side of section 12, T. 133, R. 45, 1083 feet. Here, as generally, the formation is a smoothly rounded low gravel ridge, about fifteen feet above the edge, ten or fifteen rods west, of the flat area that was covered by lake Agassiz, and about ten feet above a marsh a dozen rods east from the top of the beach.

Sill of Rudolph Niggeler's house in the S. E. ¼ of section 26, Akron, 1076. This is on a portion of the beach extending about a third of a mile from south to north; a quarter of a mile to the north its elevation is 1082 feet. In the northeast part of section 35, and in the north half of section 26, Akron, this beach is interrupted by sloughs which take its place for a fourth of a mile.

Beach in the south half of section 23, Akron, 1079 to 1080; in the N. W. ¼ of this section 23, 1075 to 1080.

Through sections 14, 10 and 3, Akron, the beach does not have its ordinary ridged form, but mostly is marked by a deposit of gravel and sand, lying upon a slope that rises gradually eastward. Its elevation here is 1075 to 1085 feet. In the south part of this distance, probably in the S. W. ¼ of section 14, the margin of the flat, somewhat marshy area that appears to have been covered by lake Agassiz, is very definite at 1075 feet, which thus was probably the hight of the lake here.

Beach in the S. W. ¼ of section 34, Tanberg, composed of gravel, nearly flat, twenty-five to thirty rods wide, 1084 to 1087; bordered by a depression of two to five feet on the east, and by an expanse ten to fifteen feet lower on the west.

Beach in the N. W. ¼ of this section 34, 1084 to 1087. Here the land next east does not present the usual slight hollow dividing the beach-ridge from the higher land eastward; instead is a springy belt, quite marshy, yet slowly rising two to four feet above the belt of beach gravel. Occasional hummocks about two feet above the general surface and covered by unusually rank grass six feet high, form part of this belt of marsh and shaking bog. Next to the east is a slough, about 1086, or three feet below the springy tract; and this is succeeded by a surface of moderately undulating till which rises gradually eastward.

Martin E. Renkliv's house, sill, in the S. W. ¼ of section 22, Tanberg, 1094. Shore-line of lake Agassiz an eighth of a mile west of Mr. Renkliv's, the border of a marshy flat area, not marked by a distinct gravel ridge, about 1075.

Sloughs, mostly filled with rushes and having areas of water all the year, occupy a width of one to one and a half miles next west of the shore-line and beach of lake Agassiz, and extend nearly continuous ten miles from south to north, from the middle of Akron to the south edge of Prairie View. The elevation of this belt of sloughs is 1080 to 1050 feet, being considerably lower on its west than on its east border. Along much of this distance the upper or Herman beach-ridge of gravel and sand is wanting, its place being occupied by arms of the sloughs and marshes, which reach one or two miles east of the border of lake Agassiz, to the elevation of about 1090 feet. Such sloughs extend one to one and a half miles east from the railroad water-tank next mentioned, and surround it excepting where the beach-ridge lies on the north.

Saint Paul, Minneapolis & Manitoba railway at the water-tank in section 33, Prairie View, six miles northwest from Rothsay and eight miles southeast from Barnesville, is 1088. Here a spur-track has been laid, extending about a third of a mile northward, with its north end some fifty rods east of the main line, to take ballast from the beach, which is well exhibited here and onward, having its typical ridged form. The elevation of its crest is 1091 to 1094 feet. It is composed of gravel and sand in almost equal amount, interstratified, mainly in level layers, but with these often obliquely laminated. Most of the gravel is quite fine, and the coarsest found here has pebbles only two to three inches in diameter. About half is limestone.

Beach-ridge one mile farther north, 1094; three-fourths of a mile north of the last, and close south of a ravine, 1099.

Beach about three miles north from the water-tank, probably near the middle of section 16, Prairie View, not ridged, but a belt twenty-five rods wide of gravel and sand on a slope of till that rises eastward, 1080 to 1102.

Beach, a ridge of gravel and sand of the common character, a third of a mile north of the last, 1105.

The beach in section 9, Prairie View, is spread more broadly than usual, its higher parts being 1095 to 1107. Here the beach-deposits are crossed obliquely by several broad depressions, ten to fifteen feet deep, running south-southwest. The depression east of all these banks of gravel and sand is about 1090 feet above the sea.

Beach, a well-marked ridge of gravel, in the S. W. ¼ of section 4, Prairie View, 1096 to 1098; and at John Hart's house in the N. W. ¼ of this section 4, 1103.

The hight of lake Agassiz on the line between Wilkin and Clay counties at the time of this upper or Herman beach was about 1090 feet.

The *Norcross beach* is represented by low ridges and banks of gravel and sand, 1030 to 1040 feet above the sea, from section 2 in the northwest corner of Monsen to section 17 near the middle of Taylor, on the west and north sides of the high land between the Mustinka and Bois des Sioux rivers. This was an island of lake Agassiz, as before mentioned. About the south end of the lake and through Wilkin county this beach has not been mapped, excepting small portions in section 36 in the southeast corner of Lake Valley, and in sections 23 and 24, T. 127, R. 45. From the latter it has been traced twenty-eight miles northward through Grant county and to the Red river near the west line of Otter Tail county. Its course in Wilkin county is probably about parallel with the upper or Herman beach, lying one and a half to two miles farther west. Its hight in Western, the most southwest township of Otter Tail county, is about 1045 feet, and one and a half miles east of Barnesville in Clay county it is 1061 feet.

The *Campbell beach* forms a series of gravel and sand deposits which crosses Campbell township diagonally from southwest to northeast, having a hight 980 to 990 feet above the sea. Its course northward through Wilkin county is not mapped. Within a few miles north of the Red river it is finely developed in the vicinity of Everdell, eight and a half miles east of Breckenridge and 992 feet above the sea. It is also well shown about a half mile southeast from Manston, where it has nearly the same elevation, forming a swell ten to fifteen feet above the land on its west side.

In section 30, Mitchell, the *McCauleyville beach* is a broad flat swell of gravel and sand, about 975 feet above the sea. It is five to ten feet or more above the general surface of till on the east, while westward a flat plain of stratified clay and fine silt, 25 to 35 feet below this beach, extends three miles to the Red river. Where the McCauleyville beach is crossed by the Northern Pacific railroad in Clay county, its hight is 983 feet. These three lower beaches of lake Agassiz are doubtless distinctly traceable through these counties. At the points where they have been examined, they are as conspicuous as the upper or Herman beach, and are similar to that in their material and contour.

Recent alluvium adjoining the Red river begins in the vicinity of Breckenridge, where it is about five feet thick. Its depth, and the width that it covers, increase northward, its width along the west side of Wilkin county being from two to five miles. At McCauleyville its depth is about 50 feet, and at Moorhead and Fargo, 100 feet.

The following records of wells include many additional notes respecting the drift deposits, beaches, and alluvium.

Wells in Wilkin county.

Prairie View. James Strachand; sec. 12: well, 55 feet deep in till, to sand from which water rose immediately twenty-six feet, sweeping up sand so as to fill the lower six feet of the twelve-inch boring.

N. G. Robbins; sec. 14: well, 35 feet; soil, 2; yellow till, 8; dark bluish till, harder but spaded, 25 feet and reaching deeper; water seeped seven feet above the bottom; well now disused, because of caving.

Tanberg. Charles Hanson; sec. 26: well, 22 feet; soil, 2; yellow till, 12; blue till, 7, not much harder than the yellow, both being spaded; iron-rusted gravel, 1 foot and perhaps continuing deeper, from which water rose six feet.

Amund Boe; in the same sec. 26, on a swell of land: well, 45 feet; soil, 2; yellow till, 15; gravel and sand, 5; and coarse sand, yellowish gray, for all the remaining 23 feet to water.

T. 132, *R.* 45. I. N. Beem has a flowing well on the N. W. ¼ of sec. 8.

John Gadbaw; S. E. ¼ of sec. 26: well, 23 feet; yellow till, 18; dark bluish till, moister and easier to dig; 5; water seeps from sandy streaks.

Bradford. There are several flowing wells in the north part of this township, within a few miles south of the Red river.

C. W. Keyes; S. W. ¼ of sec. 31: well, 61 feet; soil, 2; yellow till, 19; gravel and sand, 2 feet; blue till, mostly very hard, 38; and extending lower; water comes mainly from the gravel and sand, and stands permanently about six feet below the surface.

Champion. Col. C. H. Brush & Co.; Fountain Valley farm, sec. 3: well, 66 feet; till, 56; and sand, 10 feet and continuing deeper, from which an artesian flow is obtained. The diameter of the pipe is one foot, reduced below to seven inches. A large stream of very clear cold water constantly flows from this well, its estimated volume being seven or eight barrels per minute, or about 250 gallons. When seen by me in 1881, it had been flowing at this rate more than a year. This water is of excellent quality for house and farm use, but is hard and slightly irony, and deposits a rusty sediment in the channel of the stream. Its temperature is 46 degrees Fahrenheit.

Frank Matthew; N. W. ¼ of sec. 6: well, 50 feet; soil, 2; yellow till, 4; blue till, soft and sticky, 42; drier, very hard till, 2; to quicksand, found to be at least two feet thick, from which water rises to the surface and overflows. This well was bored in May, 1881; when seen four months later, it was partly filled with sand, and its rate of flow was one quart in a minute or twelve barrels in twenty-four hours. The water is similar to the preceding.

Jeremiah Collins in sec. 12 has a flowing well, 55 feet deep, like the two foregoing in the deposits passed through and in the quality of water; its flow is half or two-thirds as great as on the Fountain Valley farm.

Other flowing wells, or fountains, are in sec. 13, on land of Charles B. Hosford and William Tibbetts.

Manston. Railroad well in village, 28 feet; soil 2; yellow and then blue till, 26; water rose fourteen feet from the bottom. Several pieces of lignite up to three inches in diameter, and masses, also three or four inches in diameter, of selenite (gypsum) crystals, were found in this till. The water of this well and the next has a somewhat bitter flavor.

Venoss & Iverson; also in the village: well, 15 feet; soil, 2; yellow till, 6; sand, ½ foot; and dark bluish till, 7, and extending deeper; water seeps.

H. G. Stordock; sec. 28, on the Campbell beach of lake Agassiz, a half mile southeast from the depot: well, 16 feet; soil, 2; gravel, containing pebbles up to one and a half inches in diameter, 1 foot; coarse sand, 6 feet; blue clay, 8 inches; and fine quicksand, full of water, 6 feet and extending below; the water is of excellent quality, not very hard.

T. 132, *R.* 46. Spencer E. Davis, in the N. E. ¼ of sec. 23, has a flowing well, reported to be about 50 feet deep.

Horace Reynolds; W. ½ of sec. 24; well, 11 feet deep, about fifteen feet above the Red river; soil and sand, 2; yellow till, 4; harder blue till, 5.

Campbell. The railroad well in the village, 260 feet deep, went all the way in till, excepting occasional layers of sand and gravel, mostly thin, but at one place eight feet thick, from 165 to 173 feet below the top. Numerous fragments of lignite were found in the till in this well, especially from 125 to 150 feet; and they were abundantly mixed with the thick bed of sand mentioned, making about ten per cent. of the deposit; some of its pieces brought up from the depth of 173 feet were encrusted with pyrite. The lower portion of the pipe becoming filled with mud, it was found necessary to puncture the pipe and admit water above the clay filling. This was done at 176 feet. The water rose within four feet of the surface. Higher water-bearing veins were encountered in boring the well, at 125, 150 and 165 feet.

Pacific House; in the village: well, 47 feet; soil, 2; yellow till, 15; dark bluish till, 30; a layer of sand one foot thick in the lower till 34 feet below the surface supplies the water of this well, which rises to within six feet of its top.

Robert Glover; sec. 10: well, 53 feet; soil, 2; yellow till, 12; harder blue till, increasing in hardness downward, 39; the only water obtained came from a vein of sand eight inches thick 25 feet below the surface, and rose slowly to four feet below the top of the well.

N. O. Clark; sec. 15: well bored 102 feet, obtaining no water; probably in till all the way; about 80 feet below the surface a pyritous layer was found, about one foot thick, containing small shells, and a few feet lower were fragments of large lamellibranch Cretaceous shells.

Lewis S. Johns; S. W. ¼ of sec. 28: well, 65 feet; all till to the bottom, where water, issuing under great pressure from a bed of sand, suddenly threw up the auger and shafting several feet, and immediately rose to two feet below the surface. The water is excellent and supplies a half dozen families for drinking and cooking purposes. It may be pumped or drawn down 45 feet to the sand that partly fills the well; then it rises again to its permanent level in two hours.

Mitchell. Lesley, Wilson & Stouch; well, 25 feet deep, near the centre of the south side of sec. 22; soil, 2; yellow till, 6; sand, ½ to 1 inch; much harder, dark bluish till, 17; water seeps, becoming fifteen feet deep. The upper till of this well and others in its vicinity crumbles, losing its coherency, on exposure in the air; but the lower till dries under the same conditions in a hard and compact mass.

James Nolan; W. ½ of sec. 24: well, 12 feet, all yellow till, containing numerous rock-fragments, on one of which distinct glacial striæ were seen.

Cyril Boutiette; sec. 26, three-fourths of a mile southwest from the last, on the Campbell beach, here five to ten feet above the land on each side: well, 10 feet deep, all gravel and sand.

C. R. Gleason; N. E. ¼ of sec. 28: well, 27 feet; soil, 2; yellowish gray till, 6; gray sand, ½ inch; much harder, dark bluish till, 18 feet, containing plentiful rock-fragments up to six inches in diameter; underlain by sandy black mud, in which were many small gasteropod shells. This doubtless interglacial fossiliferous layer, and an interglacial forest-bed found under twelve feet of till at Barnesville in Clay county, both within the area that was covered by lake Agassiz, show that there was a sufficiently long warm epoch in the midst of the great ice age as to cause the ice-sheet to retreat from this state and far to the north, till the lake pent up by it in this basin found drainage into Hudson bay, leaving the Red river valley as an interglacial land surface.

J. J. Shen; S. E. ¼ of this sec. 28: well, 19 feet; soil, 2; yellow till, 2; dark bluish till, 15, all spaded; water seeps.

Frank H. Elwell; N. E. ¼ of sec. 30: well, 11 feet deep, situated on the McCauleyville beach of lake Agassiz; all gravel and sand, mostly very fine white sand; water excellent. Mrs. H. H. Elwell's well, in the S. W. ¼ of this sec. 30, on the same beach deposit, is 12 feet deep, all gravel and sand, to excellent water, not so hard as is usual in western Minnesota. Another well an eighth of a mile south from the last, in the same quarter-section, on land ten or fifteen feet lower and below the beach, is 10 feet deep, being soil, 2; sand, six inches; yellow till, 2; and harder blue till, 6.

T. 136, *R.* 48. Powell brothers' farm; sec. 14: well, 70 feet; soil, 2; yellowish gray, stratified clay (alluvium), 15; dark bluish, stratified, alluvial clay, soft and moist, especially below, 41; and dark bluish till or boulder-clay, very hard, 12; while a man was at work excavating this till, first loosening portions of it with an iron bar, water burst in from a layer of coarse gravel at the bottom and rose so fast that he was obliged to leave the bar in his hurried escape. In three-fourths of an hour the water rose sixty feet to its permanent level, which is about twenty-five feet above the Red river, three miles distant to the west; it is excellent water, having about the same hardness as that of the river.

McCauleyville. James Nolan; in the village: well, 33½ feet deep; soil, 2½; brownish yellow alluvial clay, 26; dark quicksand, 4; gravel containing shells, like the bottom of a lake, with water, 1 foot and extending lower.

J. H. Langevin; also in the village: well, 137 feet deep; soil, 2; yellowish alluvium, 13; dark bluish alluvium, 25; sand and gravel, with offensive water, 3 feet; below this was dark bluish gravelly till, containing pieces of lignite and Cretaceous shale and granite boulders, to the bottom, perhaps including the whole 94 feet, and continuing deeper; about a hundred feet below the surface this contained a layer some six feet in thickness of very fine blue clay which makes a good polishing material. No water in amount sufficient for use was found in this well, and it was refilled. In Mr. Langevin's cellar, and in David McCauley's cellar, about eight rods farther south, many large bivalve fresh-water shells and small gasteropod shells were encountered in the alluvial clay, about five feet below the surface and twenty feet above the Red river, which rises in its highest stage to the general level of the ground where these cellars are dug. This and most of the village is five or six feet below the flat plain which begins within a short distance to the east.

In Cyril Boutiette's well in this village, about twenty-five feet above the river, alluvial clay extended to the depth of 45 feet, where was found a layer of abundant remains of rushes and sedges, some of them having their flowering and fruiting panicles and spikes distinctly preserved.

In a well at Fort Abercrombie, opposite McCauleyville, numerous clusters, several inches long, of beautiful selenite crystals were found in the alluvial clay, under which was till with plentiful boulders. These crystals also occur on the slope of the west bank of the Red river two to three miles farther north, being found from the water's edge up to a line about four feet below the general surface.

John B. Waling; sec. 25, in the west edge of McCauleyville, four miles southeast from the village: well, 20 feet; soil, 2; yellow clay, changing below to dark bluish till, containing many rock-fragments up to three or four inches in diameter, and rarely boulders two or three feet in diameter, spaded, 8 feet; dark bluish till, very hard, picked, 4; till, partly hard and partly soft and of yellowish color, 6; water seeps. In this vicinity shells, like those of sloughs, are often noticed in plowing and in digging, to a depth of six feet.

T. 133, *R.* 47. Edward Connelly; sec. 21: well, 28 feet deep, near the brink of the bank of the Red river, which has a hight of about twenty-five feet, slightly above the highest floods; the river-bank and section of the well consist for the upper 11 feet of gravelly and stony till, and this is underlain by a heavy bed of gravel and sand that extends to the river-level and below. The water in the well rises and falls as the river varies in hight; but at the time of ordinary low water in the river, the gravel bed is doubtless filled with water by inflow from higher levels, and is slowly drained toward the river by hydrostatic pressure. About two-thirds of the pebbles in this gravel are limestone; and a block of limestone about four feet square, belonging to the till, lies on the river-bank a half mile distant southeastward.

Breckenridge. The railroad well at the engine house, 102 feet deep, was all the way in dark bluish till, or boulder-clay, excepting a small thickness of yellowish alluvial clay at the snrface; no layers of sand and no water; numerous fragments of lignite were found, up to four inches in length.

The following wells, situated in the village, are reported by Prof. Winchell in his discussion of "The water supply of the Red river valley" (*Sixth annual report*, pages 9 to 42).

Sanders' hotel: well, about 35 feet; mucky, black soil, no stones, 2½ feet; fine clay, without stones, the same as seen in the river-banks, 16 feet; gravel, small pieces of limestone, and granite boulders, with some layers of clean sand, 10 or 12 feet; under the last, which furnished water, was an undetermined thickness of a black or blue-black clay, that had a different odor. This contained stones and boulders, one of which stopped the further sinking of the well.

Town well, 34 feet deep: soil and clay, 4 feet; dark till, with no water, 30 feet; to gravel and sand, from which water rose sixteen feet in a few minutes.

Peter Hanson: well, 55 feet; fine clay, horizontally stratified, as in the river-banks, 4 or 5 feet; dark, hard till, 50 feet and reaching deeper; water seeps very scantily.

Charles B. Falley; well, 30 feet; black soil, 4 or 5 feet; light-colored clay, with some sand, without stones, crumbling in the air, 24 feet; to sand, from which water rose seventeen feet.

Professor Winchell remarks of the stratified clay in this vicinity that "it seems to have been deposited on a slightly uneven upper surface of glacier clay, or unmodified drift, so that it here only occupies the depressions in the glacier clay." In descending the Red river by boat to McCauleyville, Prof. Winchell observed that, after passing Mr. Connelly's, before mentioned, the stratified clay became more and more developed, and at last continuous, with a thickness of 25 or 30 feet, equal to the hight of the entire banks above the river, with ouly occasional exposures of till near the river-level, it being last seen about two and a half miles above McCauleyville, near the rope-ferry. Before reaching this place, the large boulders, which appeared frequently in the river for some miles below Breckenridge, had entirely disappeared

Wells in Traverse county.

Tintah. A well at the railway station, 55 feet deep in till, dug in 1871, had supplied an artesian flow of water during eight years when it was seen by me in 1879. It had then become half filled by caving in, and the flow was only a very small rill. Another flowing well is about four miles farther southeast, at the railway section-house.

T. 127, *R.* 45. C. E. Collins; sec. 42: well, 14 feet; soil, 2; yellow till, 12; water two feet deep seeps from the lower part of this till.

Leonardsville. Patrick Leonard; at the middle of the east side of sec. 4: well, 76 feet; yellow till, 25; and dark bluish till, 51, to water in gravel and sand, from which it rose forty-five feet in twenty-four hours, and within a few days gained its permanent level fifteen feet below the surface.

Joseph B. Comer; in the fractional section west of the N. W. ¼ of sec. 18: well at the stable, 16 feet; soil, 2; gravel and sand, 1½; moist yellow till, spaded, 12½; water seeps, enough for twenty head of cattle, permanent through the dry season.

Monsen. John Peterson; S. W. ¼ of sec. 2, in the northwest corner of the township, on the Norcross beach of lake Agassiz upon the high land between the Mustinka and Bois des Sioux rivers; well, 17 feet; all gravel and sand, most gravelly in its upper part; water excellent, about four feet deep.

Lake Valley. Alfred Schedin; N. E. ¼ of sec. 22 in the west part of the township, on a flat tract some four miles wide, through which the Mustinka river flows, elevated 30 or 40 feet above this river and lake Traverse: well, 21 feet; soil, 2; clay and sand, 1 foot; sand and gravel, interstratified in layers from a few inches to a foot in thickness, 18 feet and continuing lower; this well has two feet of water, which is of excellent quality, cold, much softer than the water obtained by wells in till in this region, and inexhaustible.

D. O. Westman; N. W. ¼ of sec. 24 in the west part of the township, on the southeast edge of the same plain as the foregoing: well, 41 feet; soil, 2; yellow stratified clay, 4; same mixed with quicksand, 5; dark, very hard till, 29; and white gravel, 1 foot and continuing deeper, from which water rose twenty-six feet in two days.

Windsor. A. E. Ludwig; S. E. ¼ sec. 24: well, 56; soil, 2; yellow till, partly spaded and partly picked, 25, hard, dark bluish till, picked, 23, containing occasional veins of sand and gravel one to three inches thick; and fine, gray sand, 6 feet and extending lower; good water, about two feet deep. Other wells in this township, 18 to 30 feet deep, generally obtain good water. Lumps of lignite are occasionally found, usually not exceeding six inches in length.

Arthur. Thomas Flood; sec. 21: well, about 90 feet; soil, 2; yellow till, 30; softer, moist and sticky blue till thence to the bottom, where water was found in sand and rose nearly to the surface.

James Moroney; S. E. ¼ of sec. 25: well, 45 feet; soil, 2; yellow till, 10; softer blue till, 33; water seeps, scanty.

William Moroney; three-fourths of a mile west from the last, on the S. W. ¼ of the same section: well, 10 feet; soil, 3; yellow till, 7; water issues at the bottom in ample supply from sandy streaks in the till.

Folsom. Augustus Lains; in the south part of sec. 14, three and a half miles northeast from Brown's Valley and about 125 feet above lake Traverse: well, 110 feet; soil, 2; yellow till, picked, 38; softer, dark bluish till, 50; dark gravel, 5 feet, containing pebbles up to four inches in diameter, some of them being distinctly marked with glacial striæ, like those of the till; hard, grayish blue till, 10 feet, containing less gravel than the till above; and dark quicksand, 5 feet, containing water, which, however, does not rise, while a basin or reservoir to hold it cannot be maintained because of the inflow of sand.

Edwin S. Beck; N. E. ¼ of sec. 21, two miles northeast from Brown's Valley, and, like the last and the next, about 125 feet above lake Traverse: well, 95 feet deep, in the same succession of drift deposits as Mr. Lains' well, similarly finding water which cannot be used by reason of quicksand. Another well on Mr. Beck's farm, about forty rods northwest from the foregoing and probably fifty feet lower, is 38 feet deep, being soil, 3; gravel, 7; yellow till, 20; sand and gravel 5; and yellow quicksand, 3, full of water which does not rise; this well is exhausted by pumping one barrel, but it quickly fills again to this amount.

W. C. Howard; S. W. ¼ of sec. 26, two miles east of Brown's Valley: well; 55 feet; soil, 2; yellow till, 8, very hard in its lower part; dry sand, 10; and very hard yellow till, 30, with water seeping from its base, but not rising; a reservoir was dug for it 5 feet in the hard, dark bluish till which next succeeds below.

Traverse House, owned by H. L. Prescott, in Brown's Valley village: four wells dug here have failed to obtain water, though one of them reached the depth of 110 feet; the section is soil, 2; coarse gravel, about 5 feet; and dark bluish till below. Others in this village have a good supply of water in springs, or in wells only 10 to 25 feet deep, some of which are on the plateau of till, a half mile long and a third of a mile wide, which lies at the south edge of the village and close east of the Minnesota river, having an elevation 30 to 40 feet above other portions of the valley surrounding it.

The fame of the Red river valley for its large harvests of "No. 1 hard" wheat, averaging twenty bushels to the acre, is nearly equaled by the unenviable reputation of the water supplied by its wells. The drift upon this part of the state contains much of the carbonates and sulphates of lime and magnesia, derived from the Cretaceous strata which covered this area and were plowed up by the ice-sheet, mixed with much drift from the region of granites, gneiss and crystalline schists on the northeast, and redeposited as till. These alkaline ingredients of the soil are often seen in the dry season forming a white or gray efflorescence, resembling frost, sometimes a quarter of an inch thick.

Wheat thrives better where the soil contains a considerable proportion of these alkaline salts, so that their presence throughout the Red river valley is one principal cause of its superiority in wheat-raising; and this, grown year after year, gradually takes away these ingredients and prepares the land for other crops. But their effect as dissolved everywhere in wells and streams partly offsets this benefit, and makes the water of all this region objectionably hard, and often in wells and springs noticeably bitter or salt, especially in the northern part of this valley, both in Minnesota and Dakota.

These waters, too, more readily than pure water, decompose the wooden curbing, which, being the most convenient and cheapest material, is too commonly used in this region destitute of stone-quarries. Usually these wells after a few weeks or months become offensive to taste and smell; the water is discolored, gives off sulphureted hydrogen, and horses and cattle refuse to drink it or are made sick by it. Let such wells be pumped so as to fill them with new water every day, and these offensive qualities are principally removed Instead of wood the material for lining wells ought to be stone, iron pipe or bricks, the last of which may be made almost anywhere from the stratified clay along the Red river, of excellent quality and at moderate cost.*

MATERIAL RESOURCES.

The value of the soil for agriculture, which is the chief source of wealth for this region, has been already noticed.

No water-power has been yet utilized in these counties; but excellent locations for its use occur along the course of the Red river in Wilkin county at Breckenridge and eastward.

Boulders may usually be gathered from the till in sufficient numbers to supply the masonry of farm buildings, but there are no outcrops of rock for quarrying. Magnesian limestone forms a considerable proportion, in some

* Compare the sixth annual report.

localities a half or even three-fourths, of the boulders; but it has not been burned for lime here because of the high cost of fuel.

Brick-making was begun in 1880 by Joseph Hall, in the north edge of section 5, Breckenridge, on the east bank of the Red river about one mile north of the town. His product the first year was 350,000, sold for $12 per thousand. The bank of the river here is about twenty feet high, being soil, 2 feet; stratified clay, used in this brick-making, yellowish above and dark gray below, about 8 feet; underlain by yellowish gray till. The bricks are pinkish in color. They require the addition of a third part as much sand as clay; and good sand for this purpose is obtained from an alluvial deposit beside the river forty rods farther north.

Sand for plastering is obtained by dredging from the bed of the Red river near the mouth of the Bois des Sioux, costing $1 per load.

Springs. Numerous springs issue at the foot of the bluffs along the shore of lake Traverse. They are often more or less impregnated with iron, and are always very hard water, because of the carbonates of lime and magnesia in solution, which are frequently deposited in a porous mass that encrusts moss and leaves and is hence called "petrified moss." A notable deposit of this kind is formed by a spring about fifteen feet above lake Traverse, four miles northeast from Brown's Valley.

The St. Gabrielle springs in the N. E. ¼ of section 17, Champion, three miles east-southeast from Campbell, are described as follows by Prof. Winchell in the sixth annual report. "Although there is a scummy deposit of iron running from them, the water tastes alkaline, and is very much like the water of the deep well at Campbell. There is a boggy area of about two and a half acres, lying a few feet above the stream (Rabbit river), from which the water of the springs runs into the creek. This area is in a bend of the stream, and lies about six feet below the general level of the prairie. The stream is about twelve feet below the prairie, and empties into Bois des Sioux river. It is a small stream and has clear water, but an imperceptible current. In some of the springs which are scattered over the boggy area mentioned, there is a light-colored sand seen boiling up with the water, and in the sand are also some weathered small shells. The bog itself is peaty, and shows some small fresh-water shells. The banks of the stream show nothing but the usual gray drift-clay, containing boulders of granite and many pieces of limestone.

ABORIGINAL EARTHWORKS.

Many artificial mounds of the usual dome-like form, two to ten feet high, are situated on the top of the bluffs in Dakota west of Brown's Valley and the south end of lake Traverse.

Two-thirds of a mile southeast from Brown's Valley, four such mounds, two to four feet high, lie on the verge of the bluff, close beside the carriage-road.

On Pelican hill, a knoll on the crest of the bluff of lake Traverse, about twenty-five feet higher than the adjoining portions of the bluff, two miles northeast from Brown's Valley, is an aboriginal mound two rods across and three feet high. Some of the limestone blocks that abound on this knoll, constitute a part of the mound, which seems to have been banked up around these ice-transported rock-masses.

In the S. W. ¼ of the S. W. ¼ of section 28, Windsor, three aboriginal mounds lie close west of a school-house. The most eastern of these is about fifteen feet high and a hundred and fifty feet in diameter; the middle one is about five feet high; and the western one, ten feet. There are also two mounds, about eight and five feet high, on the S. W. ¼ of the N. E. ¼ of this section 28. In both places they are near the line of bluff that overlooks lake Traverse, and mounds five to eight feet high are found in several other places along the top of this southeastern bluff of the lake.

In Wilkin county, one mound five feet high was seen an eighth of a mile southeast from the school-house which is in the southeast part of the village of McCauleyville; another of similar hight was observed about an eighth of a mile southeast from Mr. Connelly's, beside the road to Breckenridge; and a third of about the same size is reported on the north side of the Red river near an old ford about a dozen miles east of Breckenridge.

CHAPTER XX.

THE GEOLOGY OF OTTER TAIL COUNTY.

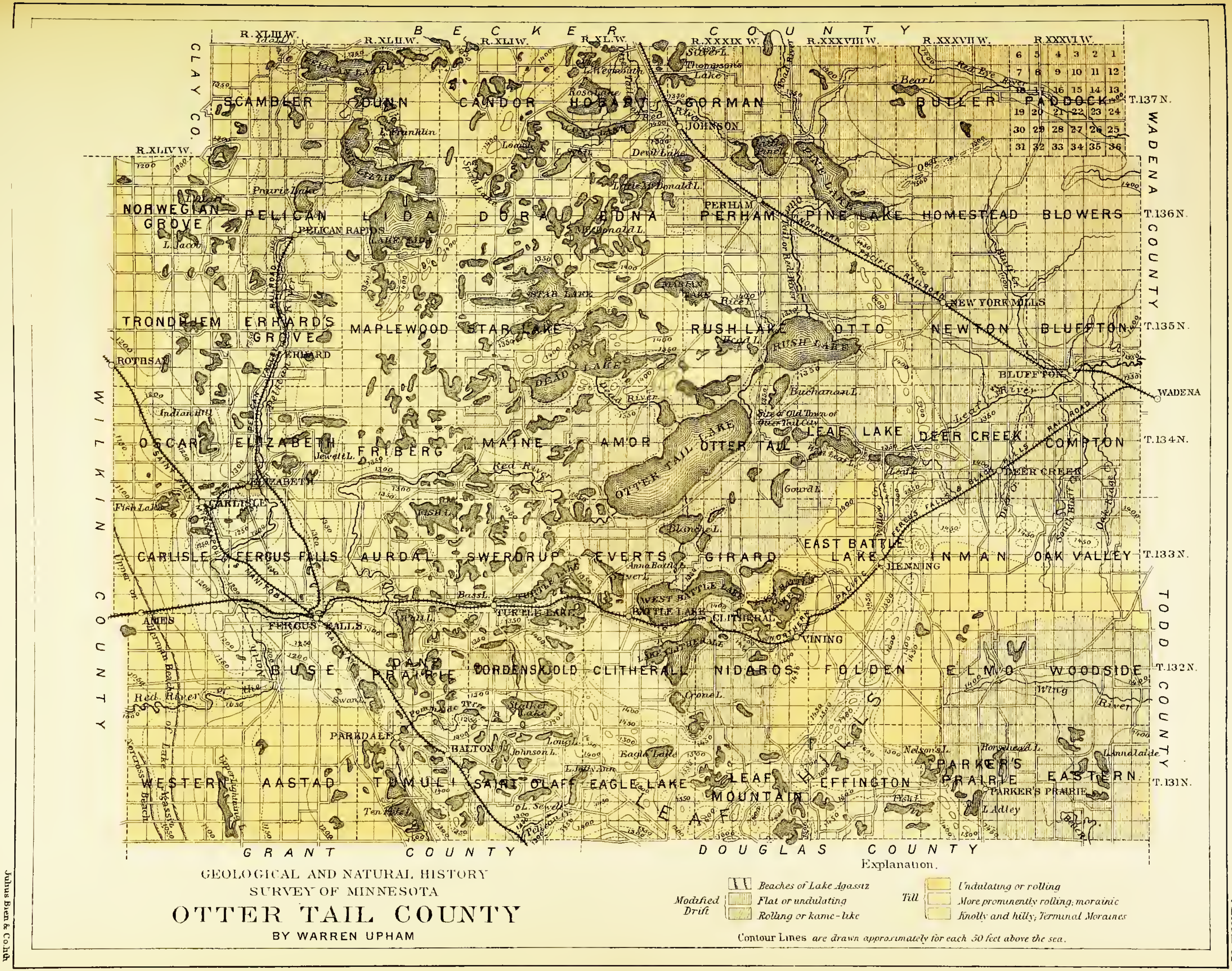
BY WARREN UPHAM.

Situation and area. Otter Tail county (plate 51) lies in the central part of western Minnesota. Fergus Falls, its largest town and county seat, is distant in a direct line about 160 and 170 miles, respectively, to the northwest from Minneapolis and Saint Paul. The other most important towns and villages are Perham and New York Mills, on the Northern Pacific railroad; Carlisle, northwest of Fergus Falls on the Saint Paul, Minneapolis & Manitoba railway; Elizabeth and Pelican Rapids, on the Pelican river; Parkdale, on the head-stream of the Pomme de Terre river; Clitherall, at the north end of Clitherall lake; Balmoral, on the southeast side of Otter Tail lake; and Parker's Prairie, near the southeast corner of the county.

The length of Otter Tail county from east to west is nine townships or fifty-four miles, and its width is seven townships or forty-two miles. It is a rectangle, excepting a deficiency of one township from its northwest corner, leaving its area sixty-two governmental townships, each six miles square, amounting to 2,240.20 square miles, or 1,433,726.44 acres, of which 162,748-.67 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The greater part of this county lies within the basin of the Red river of the North, which this report, following the example of Owen, calls by this name from the mouth of Otter Tail lake. This is forty-two miles east of its junction with the Bois des Sioux river at Breckenridge, where the Red river turns its course ninety degrees, thence flowing north. The name Otter Tail river is restricted to the chief head-stream of the Red



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
OTTER TAIL COUNTY
BY WARREN UPHAM

Julius Bien & Co. lith

river system; which flows to the south fifty miles from the north side of Becker county, passing through Elbow, Many Point, Hight of Land, Pine and Rush lakes, besides others of less size, and emptying into Otter Tail lake. Only one considerable stream is tributary to the Otter Tail river in this county, namely, Toad river, which flows into the north end of Pine lake. Dead river, the outlet of Dead and Star lakes, which flows into the northwest side of Otter Tail lake, and the outlet of Clitherall, East and West Battle lakes and others, flowing into the southeast side of Otter Tail lake at Balmoral, are also large streams.

Pelican river, which joins the Red river from the north three miles west of Fergus Falls, being its only notable tributary above Breckenridge, is forty-five miles long in straight line, having its head-waters in southwestern Becker county. It receives the waters of many lakes, of which the largest are Detroit, Cormorant, Pelican, Lizzie, and Lida.

In the east part of Otter Tail county are the sources of the Red Eye, Leaf and Wing rivers, which send their waters eastward to the Crow Wing and the Mississippi. Streams tributary to Long Prairie river, and by that to the Crow Wing, drain the south part of Eastern and Parker's Prairie.

On the south, the farthest source of the Chippewa river is in Effington; and Saint Olaff and Tumuli, with portions of Eagle Lake, Tordenskjold and Dane Prairie, are drained by the Pomme de Terre river; both of which are branches of the Minnesota river.

Lakes. Concerning the lakes of this district, Rev. C. M. Terry wrote as follows in the ninth annual report of this survey.

"Otter Tail is the banner county of the state for lakes.* It is said by those who have given their minds to counting them, that there are 430 lakes in the county. This number of lakes is not represented on any maps that I have seen. Still the number is sufficiently large, as anyone will admit who has traveled over the county.

"A glance at the map shows that the lakes occupy the central townships of the county. The eastern and western tiers of towns have none, or a few small lakes. This distribution of the lakes corresponds with the position and bearing of the moraines. Entering the county at the north, in the town of Hobart, the general direction of this drift deposit is southwest until, in the vicinity of Fergus Falls, it tends southeast and east, and then swings northeast, where its greatest development is seen in the 'Leaf mountains,' as they are popularly called. This hilly area is gemmed with lakes. Every depression in the rough and rolling ground holds a mirror to the sky and clouds. They are of all sizes, shapes and depths. Some have outlets, the largest ones especially; others have none, except in very high water; others have no outlet whatever at any time. Of some the water is whitish or clouded, holding in solution mineral substances derived from the clays and gravels of the shores. Others are apparently perfectly pure, colorless and sparkling.

"It is manifestly impossible to examine all these lakes in a single season. Only those were selected which are typical or in some respects remarkable. Of the smaller lakes, lake Sewell in Saint Olaff is as good a representative as any other. It is about two miles long and half a mile wide. The shores are not

* According to Rev. J. B. Hingeley, there are 1,029 lakes, by actual count, in Otter Tail county, not including sloughs and ponds. [N. H. W.]

very high and generally slope gently to the water's edge. There is a fringe of trees and shrubs of the common species about the lake, but most of the country is massive rolling prairie with frequent lakelets and sloughs. It was ascertained by sounding that the lake is 35 to 40 feet in the central or deeper parts. As there is no erosion of the banks the waters are quite pure and free from mineral substances. The bottom or floor of the lake is clay covered by gravel stones, and the beaches are deposits of sand and pebbles.

"In all these smaller lakes the same features are repeated over and over. A large number of these lakes have no visible outlet except in very high water. The channel of the outlet is grass-grown and dry, except a few weeks or perhaps a few days in the year.

"Lake Clitherall is a beautiful sheet of water, nearly four miles long and one mile wide. It has a deep bay extending toward the south, a distance of two miles. The south shore is densely wooded and presents to the observer on the north side a very picturesque appearance. The shores at various points are bold and high, and there is a fringe of forest trees on the north side also, where the village of Clitherall stands. There are one or two bars extending nearly across the lake, so that the water does not lie in one continuous basin. Our soundings gave for the east part of the lake a depth varying from 15 to 44 feet, and for the west part from 10 to 32 feet. The water is clear and had at the date of our visit, August 1st, a temperature of 77° F. This lake lies at an elevation of 1,332 feet above the sea. Its outlet is at the northwest side and discharges into West Battle lake.

"West Battle lake lies in two basins. The western half is nearly twice as wide as the eastern. The shores are in some places bold and abrupt, rising 40 to 60 feet above the lake. At other points the prairie slopes gently down to the water. There is not much forest. Nearly all the surrounding country, especially at the western extremity, is cultivated prairie. The lake is over six miles long. The western part is about two miles wide; the eastern division, about one mile wide. A high, wooded hill or promontory on the north side marks the line of division. Our soundings were made in the western part of the lake. The bottom of the lake is uneven. There are ridges and shallow places out some distance from the shore. We found repeatedly about 50 feet of water. The depths vary rapidly within short distances. The mass of the drift about these lakes is siliceous; some of these bluffs are almost pure sand; these crumble under the action of frost and weather, and are distributed over the bottom of the lake by the waves. All the beaches are sand and pebbles. There is very little vegetation in the waters of this lake.

"Owing to the purity of its water and the inequalities of depth, this lake presents the most rapid and beautiful play of colors. There is not a more charming or attractive spot in Minnesota than the vicinity of the Battle lakes. They lie in the midst of the famous Park Region. Groves, lakes, cultivated farms, unoccupied woodland, conspire to give variety and beauty to the scenery.

"West Battle lake has two inlets, one from lake Clitherall, the other from East Battle lake. Its outlet is on the north side, and after passing through several smaller lakes discharges into Otter Tail lake at Balmoral mills.

"The country around East Battle lake is very broken and hilly. The Leaf mountains lie a few miles to the south. Several small streams convey the drainage of these hills to the lakes. The basin of this lake is very irregular. There are numerous promontories, points and bays. The depth varies from twenty to forty feet. Only a small part of the lake was sounded, as no safe boat could be obtained. The hills and shores of the lake are covered with trees and shrubs. The outlet into West Battle lake has evidently run much wider and larger than now. It flows through a low meadow or swamp. and is still a considerable stream about ten feet wide.

"Otter Tail lake is the largest body of water in the county. Indeed, in this whole lake district which embraces parts of Becker, Otter Tail, Douglas, Pope and Kandiyohi counties, there is no lake which can compare with this in size. It is about ten miles long and three miles wide. Its longest direction is from northeast to southwest. It has three inlets, one from the south and two from the north. The largest of these is known as Otter Tail creek and is the outlet of Rush lake. A large inlet also flows down from Dead lake on the north. At Balmoral mills on the south side it receives the surplus waters of the Battle lake chain. The soundings were in the southern central part of the lake, going out from Balmoral mills. For a distance of half a mile or more from the shore the water is quite shallow, only six to eighteen feet. Toward the centre of the lake it deepens to forty, fifty and sixty feet. This deeper area was followed for some distance toward the head of the lake, when the high wind prevented further measurements. The temperature of the water on the 30th of July was 74° F., air 78° F. Prof. Owen took the temperature of this lake on the 18th of June, and found it 65° F., air 64° F. The water is not perfectly pure. It has the yellowish or clouded color characteristic of shallow lakes with clay bottoms and shores.

The soil on the southern side is sandy; at other points, however, the clay is exposed, and the feeders are colored by the clay deposits through which they flow.

"The lake is without islands or any bold and prominent indentations of the shore. It is therefore less picturesque and attractive than some other and smaller sheets of water. The outlet of Otter Tail lake is the Red river of the North, formerly known as the Otter Tail river. It is here 30 to 40 feet wide.

"The southeastern shores of the lake are fringed with trees. Farther north the prairie comes to the water's edge. On the western and northern shores are forests, interspersed with some fertile prairies or openings.

"Northwest of Otter Tail are several lakes of irregular shape, surrounded by forests and morainic hills and deposits of clay. Approaching Dead lake from the south, near its outlet, a fine growth of native forest trees is encountered. The sugar maple, basswood, oak, elm, ash and ironwood are especially noticeable. The lake itself is divided by bars and points, into several distinct basins and bays. The bottom is as irregular in shape as the shore line. The main body of the lake is shallow. Our soundings gave from 10 to 25 feet of water. There is a good growth of reeds, wild rice and other vegetation in the lake. There are a few small islands. The shores are full of boulders, both granite and limestone rock. It is indeed a lake of the woods, difficult of access, but wild and picturesque, a favorite haunt of water-fowl and other game. The principal tributary is a small stream which connects it with Star lake. The country to the east is rough and hilly. One hill near the outlet rises abruptly 98 feet above the water. On the north side the shores slope more gently and smoothly to the water.

"Farther still to the northwest is a chain of very beautiful lakes, lying on the west side of the great moraine and tributary to Pelican river. These are lakes Lida and Lizzie and Pelican lake. Between these lakes and on the east side, there is a fine forest of hard-wood trees of species already mentioned. On the west side the prairie stretches away toward the Red river. All the surrounding country is rolling and uneven. The largest of the three lakes is lake Lida. It is about seven miles long and two miles wide. A narrower arm, about one mile wide, extends south from the main body of the lake for two miles. The eastern shore is wooded and hilly. The western shore is more level and the forest soon gives place to the prairie.

"Between lakes Lida and Lizzie, which formerly constituted one lake, there are several old beaches, now covered with forest trees, indicating that the former level of the lake was from seven to ten feet higher than it is at present.

"The outlet of lake Lida is at the north end. It is a strong current of water, three feet deep and fourteen feet wide. The temperature of the lake on the 13th of September was 63° F., air 70°. The lake varies in depth from 10 to 40 feet. About the shores it is shallow. The water is very pure and clear. There are several fine springs about the shores. There are, in the vicinity of these lakes, a number of cranberry marshes from which, without any effort at cultivation, a good many bushels of cranberries are gathered every year.

"The southern part of lake Lizzie is quite shallow and narrow and filled with reeds and rushes for some distance out from the shore. The northern part is broader and deeper. The eastern shore is covered by forest, while on the western side the prairie, in some places, comes nearly to the lake. The country is massively rolling, and as a general rule sandy, but there are also large deposits of clay. One well, on the west side of this lake, was dug 78 feet, through sand and gravel, and another, a quarter of a mile away, 60 feet, through clay. The outlet of lake Lizzie is the Pelican river, at this point 40 feet wide and 3 to 4 feet deep. About a mile west of the outlet the river spreads out into Prairie lake, which has an area of about two square miles. The quality and temperature of the water did not differ materially from that of lake Lida. There are two small islands of about two acres each in this lake.

"Pelican lake is a very picturesque and beautiful lake with bold, high shores, wooded on the eastern and prairie at the western end. The water is very pure and sparkling. The depth varies from 8 to 40 feet. On the south side are some excellent springs. The exposures of soil on the lake shores are sandy; no clay was seen. The bottom is very uneven, especially in the south arm, which is sometimes called Fish lake. From this arm the outlet discharges its waters into lake Lizzie.

"These three lakes with seven or eight others in Becker county, which lie above them, constitute the Pelican chain and are a grand reservoir of water, feeding that river with perpetually fresh supplies."

"The course of the Otter Tail river in this county is southeast as far as Pine lake, and thence south to Otter Tail lake. The elevation of the river-bed above the sea near Perham is 1,324 feet. The elevation of Otter Tail lake is about 1,315 feet. Thus far the river has no clearly marked valley. It flows in a channel eroded by its own agency in the drift. The banks vary from 6 to 20 feet high. Sometimes there are swamp-like expansions at one side or the other of the stream. At other points the banks are perpendicular or abrupt and the river has eroded the side of a bluff. But in general the characteristics of the river are those simply of a drainage channel, carrying off the surplus waters of the region. It is commonly termed the Otter Tail creek above the lake. Below Otter Tail lake the Red river assumes a somewhat different character. Having received in the lake itself two important affluents, it flows out at the southern extremity a swift, strong current between moderately high bluffs.

"The country through which the river winds is exceedingly hilly and rough. The morainic deposits are composed of clay, sand and gravel, and the river, eroding the sides of these hills and bluffs, becomes colored by the earthy matter held in suspension, so that it is milky or whitish-yellow in appearance. It passes through three or four lakes which are little more than expansions of the river where the conformation of the surface favored the spreading out of the water. Owen finds ten of these lakes, but some of them must have disappeared, for at present there are only three or four places that can claim that distinction. The descent is quite appreciable and the current generally rapid. In fairly high water the river rushes along with great power, and a ride in a bateau is an exhilarating pleasure. The fall from Otter Tail lake to Fergus Falls is about 142 feet, the elevation at Fergus Falls being 1,173 feet above the sea. The general course of the river, as may be seen by a glance at the map, is southwest, but meantime the windings of the channel direct its current toward nearly every point of the compass. Its flood-plain as a rnle is co-extensive with its valley, which has been entirely eroded apparently by the present river."

Topography. Besides the foregoing references to the contour of the county, the reader will find in a later portion of this chapter details of its belts of morainic hills, including the Leaf hills, which are the most prominent accumulations of morainic drift in Minnesota, having a hight 100 to 350 feet above the adjoining country.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, Saint Paul.

a. *Main line.*

	Miles from Duluth.	Feet above the sea.
Wadena Junction, two miles west of Wadena	163.9	1352
Oak Ridge creek, bed, 1310; grade	165.6	1326
Leaf river, bed, 1303; grade	166.4	1315
Bluffton	166.9	1323
Bluff creek, bed, 1308; grade	167.0	1329
Little run, bed, 1328; grade	167.9	1341
New York Mills	174.8	1410
Summit 200 to 400 feet farther west	174.8	1411
Snmmit, natural gronnd, highest on this railroad in Minnesota	177.2	1433
Richland	179.8	1396
Otter Tail river, bed, 1324; grade	183.4	1343
Perham - -	185.5	1370
Summit, natnral surface	190.7	1383
Otter Tail river, bed, 1340; grade	192.6	1361
At Thompson's lake, grade	194.2	1372
Hobart	195.4	1386
Snmmit, natural ground	196.1	1404

b. *Fergus Falls & Black Hills division.*

	Miles from Wadena.	Feet above the sea.
Wadena Junction	2.0	1352
Oak Ridge creek, bed, 1334; grade	3.3	1347
South Bluff creek, bed, 1323; grade	5.4	1353
Deer creek, bed, 1378; grade	10.0	1389
Deer Creek station	10.3	1394
Summit, cutting 5 feet; grade	12.3	1419
Rock creek, bed, 1393; grade	12.7	1409
Summit, grade	13.1	1424
Willow creek, bed, 1406; grade	17.4	1420
Henning	17.9	1437
Pease prairie, general surface	19.–21.	1450
East Battle creek, bed, 1369; grade	23.5	1380
Clitherall	29.0	1346
Summit, grade	29.6	1368
Outlet of lake Clitherall, bed, 1331; grade	31.2	1340
Lake Clitherall		1332
Battle Lake station	33.0	1354
Outlet of Turtle lake, bed, 1327; grade	36.4	1339
Turtle lake		1323–1328
Maplewood	38.6	1360
Outlet of Bass lake, bed, 1327; grade	41.8	1335
Bass lake		1325–1328
Red river, bed, 1228; grade	46.5	1246
Red river, bed, 1191; grade	49.6	1204
Pelican Junction	50.5	1187
Crossing St. P., M. & M. railway	50.7	1192
Fergus Falls	51.3	1182
Red river, bed, 1145; water, 1151; grade	51.7	1175
Pelican river, bed, 1120; water, 1124; grade	55.0	1132
Summit, grade	56.0	1175
Upper or Herman beach of lake Agassiz, forty rods wide, crest, 1080, ten feet above the depressions both east and west; grade	59.5	1075
Ames	60.1	1063

Elevations, St. Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

a. *Fergus Falls line.*

	Miles from Saint Paul.	Feet above the sea.
Pelican creek, near the south line of Otter Tail county, water, 1236; grade	169.4	1249
Dalton (a summit)	175.6	1357
Pomme de Terre river, water, 1224; grade	178.3	1259
Parkdale	179.1	1274
Sand lake, water, 1185; grade	185.6	1186
Crossing Northern Pacific railroad, F. F. & B. H. division	186.1	1192
Fergus Falls, freight depot	186.4	1187
Red river, water, 1178; grade	186.5	1188
Fergus Falls, passenger depot	187.1	1208
Pelican river, water, 1149; grade	191.8	1171
Carlisle	195.4	1224
Junction of branch to Pelican Rapids	195.7	1216
Lake, water, 1218; grade	199.0	1223
Rothsay	204.0	1188

b. *Carlisle to Pelican Rapids.*

	Miles from Saint Paul.	Feet above the sea.
Junction, a third of a mile northwest of Carlisle	195.7	1216
Summit, cutting 8 feet; grade	197.4	1280
Summit, cutting 3 feet; grade	198.1	1282
Elizabeth	199.1	1255
Pelican river, water, 1228; grade	200.4	1239
Pelican river, water, 1231; grade	200.7	1244
Pelican river, water, 1268; grade	207.9	1278
Pelican river, water, 1276; grade	209.2	1289
Pelican river, water, 1280; grade	210.4	1286
Pelican Rapids	212.4	1303
Pelican river, mill-pond, water, 1301; grade	212.6	1316

Most of the following elevations of rivers and lakes are determined by exact surveys; others are estimated very approximately.

Otter Tail river and lakes.

	Feet above the sea.
On the line between Becker and Otter Tail counties	1360
On the line between Hobart and Gorman	1342
Pine lakes	1330
Two miles southeast from Perham	1326
Rush and Otter Tail lakes, estimated	1315
Leaf lakes, at the head of Leaf river, estimated	1340
East and West Battle lakes, about	1328
Blanche lake, one mile south of Balmoral, about	1325

Red river of the North.

	Feet above the sea.
Mouth of Otter Tail lake, about	1315
At the railroad bridge in sec. 33, Aurdal	1232
At the railroad bridge near the east line of the corporation of Fergus Falls	1195
In Fergus Falls, at the bridge of the St. P., M. & M. railway	1178
In Fergus Falls, at the bridge of the Fergus & Black Hills division, Northern Pacific railroad	1151
Mouth of Pelican river, about	1120
At Dayton bridge, in the S. W. ¼ of sec. 20, Buse	1064
On the west line of sec. 30, Buse	1041
Near the northeast corner of sec. 33, T. 132, R. 44	1014
On the line between Otter Tail and Wilkin counties	1000

Pelican river and lakes.

	Feet above the sea.
One mile east of Detroit in Becker county, mill-pond	1345
Detroit lake	1335
Lake Melissa, in Lake View, Becker county, about	1330
Pelican lake, about	1320
Lakes Lizzie and Lida, about	1315
Top of dam at Pelican Rapids. (This fall here is twelve feet.)	1301
At the railroad bridge near the south line of Pelican	1280
At the railroad bridge 2½ miles farther south, in Erhard's Grove	1268
One and one-half miles north of Elizabeth, near the north line of sec. 29	1230
On the line between Elizabeth and Fergus Falls, estimated	1200
At the bridge of the St. P., M. & M. railway, in the east edge of sec. 13, Carlisle	1149
Junction with the Red river, about	1120

The extremes of elevation in Otter Tail county are, the highest point of the Leaf hills in or near section 32, Folden, about 1,750 feet above the sea, and where the Red river crosses the west line of the county, 1,000 feet above the sea. Estimates of the average hights of the townships are as follows: Paddock, 1,400 feet; Blowers, 1,410; Bluffton, 1,375; Compton, 1,360; Oak Valley, 1,400; Woodside, 1,390; Eastern, 1,400; Butler, 1,425; Homestead, 1,425; Newton, 1,390; Deer Creek, 1,400; Inman, 1,440; Elmo, 1,420; Parker's Prairie, 1,440; T. 137, R. 38, 1,390; Pine Lake, 1,390; Otto, 1,390; Leaf Lake, 1,380; East Battle Lake, 1,440; Folden, 1,500; Effiington, 1,500; Gorman, 1,380; Perham, 1,380; Rush Lake, 1,375; Otter Tail, 1,340; Girard, 1,365; Nidaros, 1,430; Leaf Mountain, 1,500; Hobart, 1,390; Edna, 1,400; T. 135, R. 40, 1,375; Amor, 1,360; Everts, 1,360; Clitherall, 1,390; Eagle Lake, 1,440; Candor, 1,390; Dora, 1,390; Star Lake, 1,375; Maine, 1,360; Swerdrup, 1,340; Tordenskjold, 1,350; Saint Olaff, 1,340; Dunn, 1,350; Lida, 1,340; Maplewood, 1,380; Friberg, 1,350; Aurdal, 1,320; Dane Prairie, 1,300; Tumuli, 1,280; Scambler, 1,350; Pelican, 1,340; Erhard's Grove, 1,340; Elizabeth, 1,325; Fergus Falls, 1,250; Buse, 1,200; Aastad, 1,190; Norwegian Grove, 1,260; Trondhjem, 1,250; Oscar, 1,225; Carlisle, 1,175; T. 132, R. 44, 1,100; and Western, 1,090.

According to these figures, the mean elevation of the eastern third of Otter Tail county is approximately 1,415 feet; of the central third, 1,380 feet; and of the western third 1,270 feet above the sea; giving 1,355 feet, approximately, as the mean elevation of the whole county.

Soil and timber. The soil of the greater part of this county is the unmodified glacial drift, called till or boulder-clay. This forms the surface of most of the smoothly undulating and moderately rolling areas and of the more rolling, knolly and hilly morainic belts. Next to the surface it has become blackened by the decay of vegetation to a depth of one or two feet, which constitutes the soil proper. Below this it has a yellowish color to a depth varying from 5 to 25 or sometimes 50 feet, due to the exposure to air and percolating water, which have changed the iron contained in this deposit from protoxide combinations to the hydrous sesqui-oxide or limonite. At greater depths the glacial drift has a much darker and bluish color. This formation is made up from the eroded rock-materials of large areas on the north, and shows intermingled boulders and fine detritus from Archæan granites, syenites and crystalline schists, the magnesian limestone of the Winnipeg region, and the Cretaceous shales of Dakota. Its variety of ingredients, and notably its large proportion of limestone, not only as boulders and pebbles but in a finely pulverized condition, give a very high degree of fertility. This is developed by the ample rain-fall, which is distributed somewhat equally throughout the year, seldom to excess, and still more rarely so deficiently as to allow crops to be damaged by drought. Wheat, oats, and other cereals, potatoes, sorghum, flax, garden vegetables and small fruits, live stock and butter, are the agricultural exports.

Considerable tracts of stratified gravel and sand, belonging to the modified drift, having a flat surface or more often moderately undulating or rolling, occur on the west side of the Pelican river in Dunn, Scambler and Pelican; in Hobart, Gorman and Perham, and in the east edge of Rush Lake; about Otter Tail lake in the townships of Maine, Amor, Otter Tail, Leaf Lake, Everts and Girard; in the western two-thirds of Nidaros and the north edge of Leaf Mountain; in the northeastern townships; south of the Leaf river in Deer Creek and Compton; and in Elmo, Woodside and Parker's Prairie. The gravel and sand of these tracts consists largely of limestone, varying from one-fourth to two-thirds, and for the most part their productiveness is scarcely inferior to that of the areas of till.

Timber covers fully two-thirds of the county. From the west the prairie region extends in general to the Pelican river, to Fergus Falls, and to Swan and Ten Mile lakes; but a considerable body of timber is found in the northeast part of Norwegian Grove, and an extensive belt of woodland and oak openings reaches on the west side of the Pelican river from Erhard's Grove to Carlisle. Within the area that is mainly timbered, a belt of prairies extends quite across the centre of the county from north to south, including the plains and undulating tracts of modified drift in Gorman, Perham, Rush Lake, Otter Tail and Leaf Lake, and portions of Amor, Everts, Girard and Nidaros, and tracts of till in Clitherall, Eagle Lake and Saint Olaff, partly undulating in low swells, and partly forming the western third of the Leaf hills. Still farther east, patches of prairie several miles in extent are found in East Battle Lake, Deer Creek, Compton, Elmo and Parker's Prairie.

The southwestern limit of the pines, spruce and balsam fir is in the vicinity of the Pine lakes, New York Mills and Wadena. Farther southwest the principal forest trees are oaks, elms, ash, basswood, maples, box-elders, ironwood, and poplars, with tamarack in the swamps; and these also occur, interspersed with groves of pines, spruce and fir, in the northeast part of the county.

GEOLOGICAL STRUCTURE.

No outcrop of the rocks underlying the drift is known in this county. The mass of limestone seen by Owen in his boat journey down the Red river, occurring in the river-bank at a point a little above Fergus Falls, was only a large slab, embedded in nearly horizontal position in the bank, instead of being in place as a solid bed. Yet the great abundance of large magnesian limestone boulders found at many places in the west half of Becker and Otter Tail counties, the section through nearly 300 feet of magnesian limestone, probably the equivalent of the Lower Magnesian limestone of the Mississippi valley, in the salt well at Humboldt, six miles southeast of Saint Vincent, and the eight feet of this stone penetrated just above the Archæan rocks in the railroad well at Herman in Grant county, suggest the probability that the first ascent of high land east of the Red river valley is due, through Otter Tail, Becker, Clay, Norman and Polk counties, to a prominent escarpment of this Cambrian limestone with its associated strata of sandstone, now deeply covered and concealed by the drift. In the eastern part of the county, however, it seems most probable that the rocks immediately underlying the drift are Archæan granite, syenite and schists. Above these, patches of Cretaceous beds doubtless exist in this region; but definite knowledge of these matters can only be gained by deep wells, none of which have yet reached the bottom of the drift in this county. The depth of the drift probably varies from 100 to 200 or 250 feet, excepting the Leaf hills which add an equal amount, making its total thickness there 200 to 400 or perhaps 500 feet.

The greater part of the drift is till, both in its moderately undulating or rolling and its hilly or morainic areas. The latter have a much larger proportion of boulders than the former. Deposits of modified drift, however, cover probably a fourth part of the county, in flat or moderately undulating or rolling areas, which have been already enumerated in the remarks concerning the soil. Such stratified gravel and sand also form thin beds enclosed in the till, from which wells commonly obtain their supply of water, often under hydrostatic pressure, so that it rises considerably above the water-bearing stratum. Lenticular beds and kame-like knolls and hills of gravel and sand are also associated with the till in the morainic hills.

Terminal moraines. A rather inconspicuous belt of morainic drift extends from the northwest corner of Hobart, on the north line of this county, south-southwest to Spirit lake and lake Lida, twelve miles. It here varies from one to three miles in width. Its knolls along most of this distance rise only 25 to 50 feet, but they are much more abundant and have steeper and more broken slopes than upon adjoining areas to the east or west. At the southeast side of lake Lida it forms a range of hills 100 feet or more above the lake. These are conspicuously seen from the township of Maine, ten miles southeast. From lake Lida this moraine widens and covers the first six or seven miles east from the Pelican river, above which it rises 100 to 150 feet or more; being well exhibited for eighteen miles in the east portions of Erhard's Grove, Elizabeth and Fergus Falls. On the road from Maine to Elizabeth its hills are very numerous and irregular in outlines, short, trending from north to south more frequently than in other directions, and separated by hollows 25 to 50 feet deep. Here and for six miles southward, the contour along the Red river and about Wall lake, though within this morainic belt, is smoother than its other portions. At lake Lida these hills have their tops about 1,425 feet above the sea; thence to the vicinity of Fergus Falls this altitude gradually diminishes to 1,300, not because the hills are smaller, but because the land on which they lie slopes in this direction.

The portion of the county west of this moraine, excepting the tract on the southwest included in the basin of lake Agassiz, is mainly hilly, with the highest elevations 50 to 100 feet above the hollows, the contour being in massive and broadly rounded swells, with long gently curving slopes. In part of Dunn, Scambler and Pelican this area is stratified gravel and sand on the surface and as deep as wells reach, while for ten or twelve miles southwestward from this tract large deposits of modified drift, consisting of similar gravel and sand, are frequently found under a comparatively thin surface of till, as shown by records of wells in Trondhjem and Oscar. Probably the remarkable sloughs along the border of lake Agassiz in Tanberg and Akron in Wilkin county are caused by springs issuing from the low western edge of this modified drift. These beds of gravel and sand underlying till, and others farther south and north in the west portion of this county and Becker county, and also beds of stratified clay found in like situation in Aurdal and Tumuli, are perhaps subglacial deposits, formed during the time of the glacial recession from the Dovre moraine to the Fergus Falls moraine. The rolling and even hilly modified drift in Scambler and Pelican seems referable to nearly the same time, being deposited slightly later than the beds covered by till, after the melting of the ice-sheet had progressed so far that the rivers which had become subglacial along the last part of their course, were there uncovered, causing them to descend from the melting ice-fields directly upon the open land. Indian hill, in section 9, Oscar, affords a fine view of part of this area and of the moraine seven miles eastward, while at the west it overlooks the plain of Wilkin county, which stretches with slight descent twenty miles to the Red river. On the east side of this moraine the only prominent outlying hills are at the southeast corner of Hobart, where a gravelly ridge of irregular contour reaches two or three miles from north to south, its highest portion being about 150 feet above the surrounding country. These are the hills which one sees from Perham, looking northwest.

The greatest development of the terminal moraines within the limits of Minnesota, is in southern Otter Tail county, where these drift-hills sweep in a semicircle from Fergus Falls southeast to the south line of the county and thence east and northeast to East Leaf lake, a distance of fifty miles. In the first twenty miles, or from Fergus Falls to the north side of lake Christina, at the northwest corner of Douglas county, the moraines are divided into two or three belts of roughly hilly land, with intervening areas of smoother contour. One to two miles east of Fergus Falls is a narrow belt of irregular hills and hollows, with the crests about 100 feet above the river. This series continues one to three miles wide for fifteen miles south-southeast, through Dane Prairie and Tumuli, into the northeast corner of Pomme de Terre township in Grant county. There it partly bends east to the high hills north of Pelican lake and lake Christina, and is partly represented by the less irregular but yet prominently hilly land which lies between Pelican and Pomme de Terre lakes and and continues thence a few miles farther south. In Dane Prairie and Tumuli this moraine lies at the east side of a series of lakes, of which Swan and Ten Mile lakes are the largest. Beside the latter, in sections 27 and 34, Tumuli, the contour for a width of one-eighth to one-fourth of a mile is in very irregular short hills, 25 to 40 feet above the lake, whose trend, northwest to southeast, is parallel with the lake and with the course of the moraine. These small hills are exceedingly rocky with granitic and gneissic boulders of all sizes up to five or six feet in diameter, which frequently cover half of the ground for several rods distance. Northeast from this typically morainic line the land for a few miles is in massive hills and swells, which rise 50 to 75 feet above intervening hollows and lakes. Its least hilly portion is Saint Olaff township, which has mostly a rolling surface, in extensive swells 30 to 50 feet high. The east part of Tordenskjold is occupied by a second belt of very irregular hills, which is connected through sections 19 and 20 and the north part of sections 7 and 8 with the series that lies at the east side of Wall lake and the Red river, reaching northwest to the broad area of this moraine in Friberg and Elizabeth. The Tordenskjold hills are also joined from the north by another line of drift deposits, having a very rough contour in knolls, ridges and hillocks, 25 to 75 feet high, which extends ten miles with an average width of one mile, from section 15, Maine, south-southeast by the east side of Turtle lake. The wide moraine resulting from the union of these subordinate series continues southeast to lake Christina. Where it is crossed by the road from Clitherall to Saint Olaff, its first and highest hill is called "Dutch bluff." At the south side of this, about 125 feet lower, is a pretty lake, half a mile long, bordered all around by morainic hills. This belt of short ridges, knolls and hollows, has a width of three miles thence to the southwest.

The Leaf hills. In Eagle Lake township, at the north side of lake Christina, the last described series and that which comes from the southwest by the north side of Pelican lake, are united; and thence for the next twenty miles to the east and northeast the moraine forms a range five to three miles wide, composed of very irregular, roughly outlined hills, 100 to 300 feet high. This portion of the moraine is widely known by the name *Leaf mountains.* Occasionally this name is applied to its similar but less prominent portions in the west part of this county; and at White Earth agency I was informed that these hills in Becker county are sometimes called a branch of the Leaf mountains. Northeast of East Leaf lake, where the moraine is crossed by the road from Wadena to Otter Tail lake, its elevations rise only about 100 feet and are named *Leaf hills;* which seems a more appropriate title, and will be used in this report to include the highest part of the range. The common name has currency because they are the only hills in this part of Minnesota which are conspicuously seen at any great distance.

Approximate hights of the Leaf hills are as follows: Dutch bluff, about 1,450 feet above the sea; Leaf hills in Eagle Lake township, 1,400 to 1,500; in the northeast corner of Lund and the northwest edge of Millerville, Douglas county, 1,500 to 1,600; in Leaf Mountain township, 1,550 to 1,650; in the northwest part of Effington, 1,600 to 1,700; highest summit of the Leaf hills, thought to be in section 32, Folden, about 1,750, being 350 feet above the average elevation of the surrounding country; thence for seven miles northeastward, 1,650 to 1,600; depression where the range is crossed by Willow creek, the head-stream of Leaf river, about 1,425; hills in the next six miles north, to where the series is crossed by the Leaf river below East Leaf lake, 1,640 to 1,450.

The Leaf hills are the most massive morainic accumulations in Minnesota. In their highest portions they rise 200 to 350 feet above the adjoining country, which is itself covered deeply with drift. The top of the bed-rock beneath the Leaf hills is probably not higher than the bottom of lake Clitherall a few miles distant to the north, which is 1,288 to 1,300 feet above the sea. Fifteen miles south from the highest part of the Leaf hills, the bottom of lake Carlos is about 1,180 feet above sea-level. A gradient connecting these lake-beds would pass beneath the Leaf hills at an elevation of 1,250 feet, or 500 feet lower than the highest points of this moraine; and this thickness is very likely all drift, the top of the bed-rock being estimated to coincide approximately with the gradient mentioned. The general elevation of this entire region is thus doubtless due to prominence of the bed-rock above its hight in the valleys of the Red and Mississippi rivers on the west and east, in the same way that the preglacial contour remains to determine all the great river-basins and large areas of highland in the state; but the contour of the Leaf hills, rising in steep slopes to summits 100 to 200 and 350 feet above their bases and the intervening hollows, a quarter or a half of a mile or one mile distant, with no exposures of bed-rocks in them or in their vicinity, shows that these hills are wholly drift deposits, the underlying rock most probably not rising higher there than in other parts of this region.

The road from Alexandria to Clitherall crosses this range in the township of Leaf Mountain. The summit of the road is near the south line of this township, about 1,525 feet above the sea. The top of a hill a quarter of a mile east of this and about 125 feet higher, affords a fine view of these "mountains," which westward and northeastward rise in most tumultuous confusion 150 to 250 feet or more above the intervening depressions. They are massive, though very irregular in contour, with steeps slopes. No prevailing trend is noticeable. Between them are enclosed frequent lakes, which vary from a few rods to a mile in length, and one of the largest lies at the northeast foot of this hill. The material is unmodified drift, nearly like that which forms very extensive gently undulating tracts elsewhere. The principal difference is that rock-fragments, large and small, are generally more numerous upon these hills, and occasionally they occur in great abundance.

The Leaf hills are also crossed by the road that runs northwest from Parker's Prairie. In Folden this road winds three or four miles among their knolls, hills and short ridges, rising about 100 feet above the land on each side. Again, in going from Otter Tail lake to Wadena, this range is encountered one to two miles northeast from East Leaf lake. Here its hillocks are only 40 to 60 feet above the hollows, and 100 to 125 feet above the lake. Their material is gravel and sand with enclosed boulders, unlike the stony and gravelly clay which makes up most of these morainic accumulations. This belt of irregular hillocks and hollows, occupying a width of about two miles, next extends in a course a little west of north twelve miles, running midway between New York Mills and Rush lake. Its most northern portion traced and mapped consists of hills which rise 100 feet above the general level at the south side of Pine lake.

Outlying hills west of this series occur along the south side of the Leaf lakes, where they are 50 to 75 feet high; and for two miles south from East Battle lake, above which they rise about 150 feet. On the east side of this moraine two lines of hilly and irregular contour branch off from it. The most northern starts four miles south from the east end of East Leaf lake, and extends nearly due east through Inman and Oak Valley into the northwest township of Todd county. On the road from Wadena to Parker's Prairie this line is represented by a nearly level tract of unmodified boulder-clay, in contrast with all the rest of this road which has only stratified gravel and sand. Two miles farther east, in northwestern Todd county, it rises in conspicuous hills fully 100 feet above the general level. The other series starts from the highest part of the Leaf hills, fifteen miles south of the Leaf lakes, and passes southeast into Douglas county. In its first few miles, through Effington and Parker's Prairie, this morainic range decreases in hight from 200 to 75 feet.

Eighth or Fergus Falls moraine. When the Minnesota lobe of the ice-sheet receded from its seventh or Dovre moraine, its next pause or re-advance sufficient for the accumulation of a well-marked line of marginal drift deposits seems to have been along the course of the morainic series traced from Hobart southward by lake Lida to Fergus Falls, and by Swan and Ten Mile lakes to the north side of Pelican lake and lake Christina, this eighth or Fergus Falls moraine having been formed on the west border of the ice which still covered northern Minnesota. The southern border of the ice at this time apparently extended eastward from lake Christina along the course of the Leaf hills to their highest point, and thence southeastward through Spruce Hill in Douglas county and through southern and eastern Todd county.

Ninth or Leaf Hills moraine. Later recession of the west margin of the ice and of its portion in southeastern Otter Tail county and in Todd county, is indicated by the morainic belt that reaches from Maine township south by Turtle lake and through Tordenskjold to the Leaf hills, and farther east by the morainic hills in northern Todd county; but when these were accumulated the ice-front probably still remained with no considerable or permanent recession along the line of the Leaf hills in Eagle Lake, Leaf Mountain, Effington, and the south part of Folden. The portion of the Leaf hills farther north to East Leaf lake appears to have been formed along the east border of an ice-lobe whose west side was at Turtle lake, these morainic series on the east and west being accumulated where the ice had withdrawn considerably from its eighth or Fergus Falls moraine. The later or ninth morainic series may therefore be well designated as the Leaf Hills moraine, this and the preceding being merged together along the highest part of the Leaf Hills. The moraine continuing north from East Leaf lake to Pine lake was probably formed on the west side of the ice during a halt in its subsequent retreat, being thus the latest marginal deposits of drift in this county. Between the times of the Fergus Falls and Leaf Hills moraines, the west boundary of the ice in Becker and Otter Tail counties seems to have receded ten to fifteen miles, and in Todd county the glacial recession was from the most southern to the most northern tier of townships, some thirty-five miles.

Modified drift. By the next and much greater glacial retreat, to the tenth or Itasca moraine, Otter Tail, Becker and Wadena counties were uncovered from the ice; and very extensive deposits of modified drift, gathered from the ice-sheet by the floods produced in its melting, were spread upon these counties. Excepting the modified drift west of the Pelican river, and in Parker's Prairie, Elmo and Woodside, in the southeast corner of Otter Tail county, all the large areas of gravel and sand in this county were formed during this glacial melting and recession from the Leaf hills to the Itasca moraine. The most remarkable of these deposits is the plain of Nidaros, about six miles long from south to north and three to four miles wide, elevated 100 to 125 feet above Clitherall lake, which bounds this plain on its northwest side. The south part of this tract, extending into Leaf Mountain township, is in broad undulations, 10 to 30 feet high, having a prevailing trend from northeast to southwest. Some portions of the modified drift in Scambler and Pelican have a hilly contour, rising in smooth, gracefully curved slopes, 40 to 60 or 75 feet above the depressions and lakes. Undulations in long slopes, with elevations 15 to 25 or 35 feet above the enclosed hollows and lakes are common upon most of the areas of modified drift in this county. Its most flat tracts are in Perham, Rush Lake, Otter Tail, Nidaros, Woodside, Elmo and Parker's Prairie.

Osars. Wall lake, five miles east of Fergus Falls, receives its name from an osar of coarse gravel on its west side, through which the lake has cut its outlet. This osar is a ridge a third of a mile long, 30 to 35 feet high in its northern half and 15 to 20 feet high in its southern half. At its south end, where it abuts on the higher area of rolling till, the gravel contains boulders up to two and even three or four feet in diameter, but they are absent or very rare in its other portions. The sides of this gravel deposit have the very steep slopes characteristic of osars, but it has for the most part a level, plateau-like top, several rods wide, unlike typical osars.

No other noteworthy ridges of modified drift belonging to this class were observed in my examination of this county; but in a part not traversed by me, Mr. Edward Curo of Perham reports a very interesting osar 20 to 100 feet high, steep-sided and narrow-topped, extending some five miles east-northeasterly from section 12, Pine Lake, through the northwest part of Homestead and into the south edge of Butler, to the head of Bluff creek. Mr. Curo describes this as composed of sand and coarse gravel, constituting a single, definite ridge, with no others noticeably parallel with it or branching from it. On each side along most of its course are swamps, and in a few places the ridge sinks below the swamp-level. He is familiar with some of the remarkable osars of the state of Maine, where they are usually called "horsebacks," and he considers this ridge to be distinctly of the same character.

Kames. The Leaf Hills moraine in the vicinity of East Leaf lake consists of kame-like deposits of gravel and sand with enclosed boulders, as before stated, its elevations being 40 to 60 feet above the intervening hollows and about 100 feet above the lake. The hills five miles northwest from Perham appear to be of the same kind. They are probably in the line of continuation of the Leaf Hills moraine from Turtle lake northward. In section 22, Maine, this moraine has a width of one mile and is composed almost wholly of kame-like hillocks and short ridges of gravel and sand, 10 to 40 feet high, with no boulders, the largest rock-fragments seen being one and a half feet in diameter.

Frequent hillocks of kame-like gravel and sand occur in the township of Norwegian Grove, interspersed with swells and hills of till.

A *boulder* worthy of mention lies about forty rods east-northeast from the top of Indian hill in Oscar, on land some 25 feet below that point. It is an angular block ten feet long, as exposed, a part being under-ground. Most of this rock is light gray granite, in which are enclosed many angular fragments of black hornblende schist (hornblende and black mica) of all sizes up to one and a half feet long and one piece even three and a half feet long, making probably a fourth part of the whole mass. No other boulders of this kind were found in this region, but a similar one was observed near Correll in Big Stone county (vol. I, p. 626).

Lake Agassiz. The following are notes of the survey of the beaches of lake Agassiz in the southwest edge of Otter Tail county.

Upper or Herman beach. Beach in section 34, Western, near John F. Wentworth's, 1070 to 1075 feet above the sea; surface at Mr. Wentworth's barn, 1072.

Beach twenty-five rods east of Albert Copeland's house, in the S. W. ¼ of section 28, Western, 1070 to 1066; where it is crossed by the old road from Fergus Falls to Campbell, near the northwest corner of this section 28, 1072; through the next two miles north, finely developed, with nearly constant hight, 1072 feet, being seven to ten feet above the depression at its east side, and twenty feet above the area westward, which was covered by lake Agassiz; at Michael J. Shortell's, section 9, Western, 1073; one mile farther north, 1078; and at A. J. Swift's, in the S. E. ¼ of the N. W. ¼ of section 4, Western, 1076. The beach at Mr. Swift's and for a half mile farther north is well exhibited, and (as in many other places) is bordered on its east side by a narrow strip of marsh.

Beach in the S. W. ¼ of the N. E. ¼ of section 33, T. 132, R. 44, 1076; top of large aboriginal mound, situated on the beach here, 1082; land thirty rods west, 1060. Lakelet fifteen rods in diameter, about an eighth of a mile northeast from the large mound, 1051.

Red river near the northeast corner of section 33, T. 132, R. 44, 1014; on the line between this township and Buse, 1041; at Dayton bridge, in the N. E. ¼ of the S. W. ¼ of section 20, Buse, 1064, being eight feet below the bridge. Railroad embankment, abandoned, at Dayton bridge, about 1102. S. A. Anderson's house, foundation, in the N. W. ¼ of the S. W. ¼ of section 29, Buse, 1147.

No noticeable delta was brought into lake Agassiz by the Red river.

Beach north of the Red river, near the south line of section 21, T. 132, R. 44, 1077; in this section 21, an eighth of a mile north of the road from Fergus Falls to Breckenridge, 1079; and for the next mile north, 1077 to 1080. This is a typical beach-ridge, smoothly rounded, composed of sand and gravel that contain pebbles up to three inches in diameter; its width is thirty to forty rods; and its hight above the very flat area on its west side, which was covered by lake Agassiz, usually somewhat marshy next to the beach, is about fifteen feet. On the east there is first a depression of four to six feet, succeeded within a quarter of a mile eastward by a gentle ascent which rises five to ten or fifteen feet above the beach. The material on each side of the beach is till, slightly modified by the lake on the west. It is all fertile prairie, beautifully green, or in many places yellow or purple with flowers during July and August, the months in which this survey was made. At that time, in 1881, no houses had been built on this beach, or within a mile from it, along the first eleven miles north from the Red river; the first house fonnd near the beach being in section 26, Akron, in Wilkin county.

Beach, at a low portion, probably in the S. E. ¼ of section 5, T. 132, R. 44, 1075. A lake nearly a mile long lies on the flat lowland, about one and a half miles west from this low part of the beach. The elevation of this lake was estimated at 1055 or 1050 feet above the sea; it is only a few feet lower than the general surface around it.

Beach, probably near the north side of this section 5, 1077 to 1078. On its east side here, and for a half mile both to the south and north, is a slongh, partly filled with good grass and partly with black rushes; its width is about a fourth of a mile; and its elevation, about 1070 feet. The land west of the beach descends within one or two miles from 1060 to 1050 feet.

Beach a quarter of a mile north from the point last noted, 1072. This is a low ridge of gravel and sand, only four feet above the slough on the east, and bordered on the west by marshy grassland, which slopes gently down, five to fifteen feet below this beach-ridge.

Beach, at its lowest portion for this vicinity, within a third of a mile north of the preceding, and near the centre of section 32, Carlisle, 1070 to 1068; being only two feet above the marsh or slough on its east side. (A railroad grade, abandoned, lies a third of a mile east of this.) Beach a quarter of a mile farther north, 1077; and about one mile north from its lowest portion, 1075, cut by a ravine the bottom of which is nearly at 1063 feet. (This is some thirty rods west of the abandoned railroad embankment.) Beach a fourth of a mile north-northwest from the last, 1077.

Railroad grade, 1077, where it crosses the beach, about a mile northwesterly from the ravine mentioned. Beach here, 1076, being eight to ten feet above the slough on its east side, and having about the same hight above the marsh next to it westward. The material of the beach, shown by the abandoned railroad embankment, which is made of it along a distance of a third of a mile, is coarse gravel filled with abundant pebbles of all sizes up to six inches in diameter, fully half of them being limestone.

Beach near the west side of section 7, Carlisle, at the west line of Otter Tail county, 1083. Here it is a smoothly rounded gravel ridge, about fifteen feet above the edge of the flat area that was covered by lake Agassiz on the west, and ten feet above a marsh or slough that lies a few rods distant on its east side.

The *Norcross beach*, where it is crossed by the road from Fergus Falls to Campbell, near the west line of section 28, Western, has an elevation very nearly 1045 feet above the sea. It is a wave-like ridge of sand and gravel, with nearly flat surfaces of till or boulder-clay on each side. In crossing it, the ascent from the east is about five feet, and the descent toward the west about ten feet. The width of the ridge, inclnding its slopes, is some fifteen rods.

Ice-formed ridges. Low ridges a few feet in hight and three to six rods wide, composed of gravel and sand and frequently containing boulders, accumulated by ordinary ice during the recent epoch, were observed in the following localities: close south of Parker's Prairie, dividing a lakelet from the northeast end of lake Adley and used as a road-way; along a fourth of a mile on the east end of lake Marian, separating the lake from a swamp, likewise occupied by a road; on the northwest shore of Clitherall lake; along an eighth of a mile between lakes Lida and Lizzie; for nearly the same distance between the southeast and northwest parts of Spirit lake in Dora township; and in section 35, Candor, extending forty or fifty rods, connecting two islands of Loon lake with the west shore.

Wells in Otter Tail county.

Bluffton. George Winters; sec. 28: well, 41 feet; soil, 2; sand, 11; alternations of clay and sand in layers two to four feet thick, 22 feet; and dark bluish till, 6 feet; water rose ten feet from the bottom. Wells in this township are mostly 20 to 30 feet deep, sometimes wholly in till, but usually having five to ten feet of sand next below the soil.

Deer Creek. The two following wells are on a very level plain of modified drift which occupies the northeast quarter of this township south of the Leaf river: Bolton brothers' well, in the west part of sec. 14, 27 feet deep, all gravel and sand; and Mrs. A. N. Stillmans' well, in the southwest corner of this section, 24 feet deep, being soil, 2, gravel with pebbles up to two or three inches in diameter, 4, yellowish sand, 6, and hard till, picked, 12, yellow in its upper two feet and dark bluish below, with water at the bottom in a vein of sand, rising two feet.

Parker's Prairie. Henry Asseln's well in the village, north part of sec. 22: 55 feet deep; soil, 2; yellowish sand and gravel, 13; and hard dark bluish till, 40, and extending lower; the only water obtained seeps from the base of the modified drift, at the depth of 15 feet. This well is about fifteen feet above lake Adley, which lies within a few rods on the south. Most of the wells in this vicinity are ten to twenty feet deep, wholly in modified drift, with ample supply of water.

Gorman. Jonah Dinehart; N. E. ¼ of sec. 30: well, 30 feet; soil, 2; yellowish sand and fine gravel, 18; white sand, 5; and brown, iron-rusted sand, 5 feet, with water in its lower portion, underlain by yellow till.

Perham. Wells in the village, situated on an extensive, nearly level plain of modified drift, are 20 to 30 feet deep, all sand and fine gravel, with abundance of water.

August Mutschler; S. E. ¼ of sec. 28: well, 52 feet; soil, 2; yellowish till, containing boulders up to three feet in diameter, 8; harder and more gravelly till, also yellowish, 25; intermingled sand and gravel, with little clay, yet probably till, very hard to dig, crumbling like air-slacked lime by exposure in the air, 8; and stratified gravel and sand, easy to dig, containing pebbles up to six inches in diameter, 9 feet, with water in its lowest two feet, underlain by very hard blue till. In the bottom of this well, on the top of the underlying till, were two boulders, each weighing about half a ton. The beds penetrated by this well were all straw-colored, and were all so hard as to require picking, except the last nine feet.

Blasius Hassler; in sec. 33, a half mile southwest from St. Joseph's church: well, 70 feet, in till, yellowish above and dark bluish below; water rose from the bottom thirty feet.

Ferdinand Bœdigheimer; sec. 36: well unfinished, seen when 20 feet deep; soil, 3; gravel and sand, 9; yellow clay, perhaps till, 7; and soft dark mud, smelling like that of sloughs, one foot and continuing deeper.

Rush Lake. John Doll; sec. 12: well, 25 feet; soil, 2; all sand below, to water in quicksand.

Nidaros. Seven wells bored in this township by Mr. Henry H. Russell, of Alexandria, varying from 30 to 90 feet in depth, are all in stratified sand and gravel to water at the bottom. The deepest is Charles Lundgreen's, in sec. 18, in which the water is seven feet deep, having a permanent level 83 feet below the surface. It is situated on the high plain about a hundred feet above Clitherall lake.

Hobart. D. Wellman; sec. 2: well, 33 feet; soil, 1½; all below is sand and fine gravel. The surface in this vicinity is undulating modified drift, rising in long slopes that form swells and hills 20 to 40 feet above the lakes.

J. G. Nichols; sec. 8: well, 12; soil, 1; sand, 11. This is ten feet above Rose lake, five rods distant.

Michael Gorman; sec. 34: well, 57 feet; soil, 1; yellowish gray sand, 37; coarse gravel, 2; sand as before, 10; hard, white sand, 2; and dark bluish till, 5 feet, very hard, but becoming soft and sticky with seeping water.

Amor. Ole Sundberg; sec. 18: well, 25 feet; soil, 1½; all below is sand and gravel. Wells in this township are mostly 25 to 30 feet deep, finding only sand and gravel, with plenty of water.

Clitherall. Hans Gilbertson; N. W. ¼ of sec. 4: well 32 feet; all sand and fine gravel.

Maine. R. F. Adley; sec. 23: well, 80 feet; soil, 1½; all below is stratified sand and gravel, holding pebbles up to four or five inches in diameter. Wells in this township, excepting its southwest part which is till, are 20 to 60 feet deep, or rarely more, in modified drift.

St. Olaff. Several wells, bored by Mr. H. H. Russell in this township, range from 50 to 94 feet in depth, till being the prevailing material of them all, yellowish to the depth of about forty feet and dark bluish below. Mr. Kinney's well, 66 feet deep, in the southwest part of the township, was forty feet of yellow clay, probably till, but said to be unmixed with gravel or pebbles; clayey quicksand, 14 feet; blue till, very hard, with numerous rock-fragments, 6 feet; and gravel and sand, 6 feet, with water which rose twenty-six feet.

John Baardson; N. E. ¼ of sec. 11: well, 31 feet; soil, 2; yellow till, 6; yellow sand, 8; yellowish gray clay, 5; and sand, with water in its lower part, 10 feet.

Aurdal. A well 30 feet deep seen in sec. 23, was yellow till, 10 feet; and bluish clay, moist and sticky, containing no stones nor gravel, with water of disagreeable taste seeping from it, 20 feet and continuing below. This vicinity consists of swells and hills of till, 30 to 60 feet high. (Compare this with the next.)

Tumuli. A. Kaus; at Parkdale mills, in sec. 4: well, 22 feet; soil, 1½; yellow till, well filled with rock-fragments, hard to dig, 4; and dark bluish clay, with no intermixture of gravel or sand, but containing rarely, here and there, little fragments of rock up to three inches in diameter, easy to dig, 16 feet and extending deeper; water of good quality seeps and stands eight feet deep. This well is about a dozen rods south from A. Kaus & Son's mill. In the excavation for the mill, the till was found to be three feet deep, underlain by at least ten feet of this peculiar dark clay. On the east side of the road, two rods east of the mill and for ten rods thence to the north, a newly exposed section four to seven feet high showed the same deposits, as sketched in fig. 31. In the south half of this section the first two to four

FIG. 31. SECTION AT PARKDALE MILLS, SEC. 4, TUMULI.

Scale, 40 feet to an inch.

feet below the soil is till, and this is underlain by the peculiar clay, which in the northern half of the section rises to the surface but is there underlain at a depth of three or four feet by a layer of till one to three feet thick, under which the clay again appears in the base of the section. In this clay infrequent limy concretions were observed, besides the occasional rock-fragments. It is doubtless a deposit from water, perhaps subglacial, in which case the pebbles or rock-fragments may have fallen from the overlying ice, or perhaps in some basin temporarily formed between the ice-margin and its morainic accumulations, in which case the fragments of rock were probably dropped from thin sheets of ice frozen on the surface of the lakelet along the front of the ice-sheet and then broken up, floated away and melted. If the second hypothesis be the true one, the till was brought by a re-advance of the ice-sheet.

Scambler. Six wells reported by Mr. Russell in this township, varying from 25 to 55 feet in depth, were wholly in sand and gravel.

Pelican. Eric Rishof; sec. 7: well, 70 feet; yellow till, 20 feet; and sand, with scarcely any gravel, for the entire 50 feet below; water in abundance at the bottom.

R. E. Lacy; S. E. ¼ of sec. 21: well, 41 feet; soil, 2; yellow till, 4; and yellow sand, 35 feet to water. For a thickness of about four feet in this well, 16 to 20 feet below the surface, one side of the excavation was yellow till, while sand like that above and below occupied the other side.

Elizabeth. Louis Candeau; sec. 8: well; 58 feet; yellow till, 12; softer, dark bluish clay, probably like that forming the lower part of the next well, and perhaps the same as was observed in Aurdal and Tumuli, 26 feet; and sand in layers of different colors and degrees of fineness, 20 feet, with abundance of water in its lower portion.

Town well, Elizabeth village, sec. 32: 45 feet deep; soil, 2; white sand, 2; yellow till, 15; and moist, dark bluish clay, with no stone fragments, 26 feet; water rose eight feet from sand and gravel at the bottom.

Fergus Falls. Halvor Back and brother; in the north part of the city: well, 41 feet; yellow till, 10; dark bluish till, 31; to water in sand. Small pieces of lignite, up to three inches in diameter, are found rarely in wells in this vicinity.

A public well for use by fire-engines, at W. J. Van Dyke's store on the corner of Lincoln avenue and Court street, went 12 feet through very coarsely rocky till, and then four feet in swamp-mud, in which were tamarack stumps and roots, with trunks, branches and even the cones of these trees, forming an interglacial forest-bed.

The river-bank at the north end of the lower bridge, five rods northeast from Page & Wright's flouring-mill, consists of the same very coarsely rocky till at the top for a thickness of 6 to 8 feet, containing blocks of stone up to three feet and occasionally five feet in diameter, underlain by at least 5 feet of sand and fine gravel. Similar stratification was also noticed near Mr. Wright's saw-mill.

Buse. James Gray; in the north part of the township, one mile southwest from Fergus Falls: well, 85 feet; yellow till, 45; and yellow sand and gravel, 40, to water, which was found at the top of underlying till.

S. A. Austin; S. W. ¼ of sec. 29: well, 80 feet; soil, 1; yellow till, 35, spaded for the first ten feet but picked below, enclosing occasional thin layers of sand and gravel; and blue till thence to the bottom, 44 feet, similarly containing seams of modified drift nowhere exceeding one foot in thickness, none of them yielding any considerable supply of water, so that this well was a failure. Another well about a dozen rods distant eastward, on land some ten feet lower, gets plenty of good water at the depth of ten feet.

Norwegian Grove. Martin Johnson; S. W. ¼ of sec. 10: well, 25 feet; soil, 2; yellow till, 13; sand, 6 inches, with water; and harder, dark bluish till, 10 feet, picked, containing no sandy layers and yielding no additional supply of water.

Trondhjem. Lion H. Rud; sec. 19: well, 106 feet; till, 36; and sand and fine gravel, 70, to water at the bottom. Mr. Rud had dug four other wells before this, near it and on land of about the same hight. The record of one of these, 65 feet deep, about a dozen rods from the foregoing, was till, 20; gravel and sand, 20; gray clay, 6 inches; then, gravel composed wholly of pebbles up to four inches in diameter, with no sand, but changing below into sand, which together make up the lower 25 feet, continuing also deeper; no water. Another, about the same distance from the deep well and seven rods from the last, went 25 feet, being in yellow till, spaded, 10; and harder blue till, picked, 15 feet and continuing below; no water.

A well 85 feet deep in sec. 29 was yellow till, 25; very hard, clayey gravel, probably till, 5; and gravel and sand, 55 feet, being all fine sand in the lower part; no water.

Oscar. Michael Skolrud; S. W. ¼ of sec. 10, two-thirds of a mile southeast from Indian hill: well, 60 feet, or more; till, about 20; all sand and fine gravel below; no water.

Nels Gilbertson; sec. 21: well, 15 feet; black soil (in a depression), 4; yellow till, picked, 8; and yellow sand, with plenty of water, 3 feet, extending deeper.

Peter Gilbertson; in the same sec. 21: well, 25 feet; soil, 2; yellow till, spaded, 15; and sand 8, with water in its lower part.

Lutheran parsonage; sec. 22: well, 24 feet, all yellow till; water seeps from sandy and gravelly streaks near the bottom.

Some of the cuts made for the railroad in this township, ten to twenty feet in depth, have 5 to 10 feet of yellow till next to the surface, with stratified sand and gravel below.

Carlisle. Andrew O. Grötte; S. W. ¼ of sec. 3: well, 35; soil, 2; yellow till to the bottom, all picked, excepting a few feet at the top; water seeps, chiefly at the depth of about 30 feet, often filling the well half full, but only three feet deep in dry winters. Some of the wells in this township are 50 to 75 feet deep, wholly in till, which is dark bluish below.

T. 132, *R.* 44 Martin Goetzinger; sec. 25: well, 45 feet; soil, 2; yellow till, 17; quicksand, 22; and very hard, dark bluish till, 4 feet and lower; not much water. A boulder estimated to weigh three tons was found in the lower part of the upper till. The thick bed of modified drift is perhaps continuous with that encountered similarly by other wells along a distance of twenty-five miles thence northward, in Buse, Elizabeth, Oscar, Trondhjem and Pelican.

Western. A. Thompson; N. W. ¼ of sec. 3: well, 45; soil, 2; yellow till, partly picked, 18; softer blue till, 23; and sand, 2 feet and reaching deeper; water plentiful, two or three feet deep. Several pieces of lignite were found in both the yellow and the blue till.

A. J. Swift; N. W. ¼ of sec. 4: well, 20 feet deep, on the east edge of the upper or Herman beach of lake Agassiz; soil, 2; gravel and sand, 10; yellow till, 4; and blue till, soft to dig, 4; extending deeper.

T. B. Roberts; sec. 14; well, 14 feet; soil, 2; yellow till, 10; quicksand, 2 feet and more; plenty of water.

O. J. Sundhal; S. W. ¼ of sec. 20: well, 27 feet, on the Norcross beach of lake Agassiz, which is here a gracefully rounded ridge about twenty rods wide, five to eight feet above the depression on its east side and ten to fifteen feet above the land next west; soil, 2; gravel and sand, 10; yellow till, 8; and blue till, 7; water seeps from the till, usually standing fifteen feet deep.

Albert Copeland; S. W. ¼ of sec. 28: well, 21 feet, all gravel and sand, with pebbles up to two or three (rarely four) inches in diameter; water abundant. This is on the upper or Herman beach of lake Agassiz.

John Will; S. E. ¼ of sec. 30: well, 56 feet; soil, 2; yellow till, spaded, 12; hard sand, with a little water, 1 foot; dark, bluish till, 40 feet, very hard for the first twelve feet and the last four feet, but soft to dig in the intervening portions; and quicksand, dug into 1 foot, with water which rises only one foot above this layer.

Richard Umland; in the S. W. ¼ of this sec. 30, a third of a mile west from the last, and on land a few feet lower: well, 42½ feet, dug in June, 1879; soil and sand and gravel, with whitish streaks of calcareous matter, 4½ feet; yellow till, spaded, 12; blue till, 26, picked for the first five or six feet, but growing softer below and there spaded; sixteen hours after the last digging, in which no sign of water had been observed, water was seen entering the bottom of the well, and in four hours it rose to the surface and overflowed in a constantly running stream during the summer and autumn of that year; as no curbing was put in the lower fourteen feet of this well, that portion gradually caved in, finally stopping the artesian flow.

MATERIAL RESOURCES.

The agricultural capabilities of this district, and its ample supply of timber, have been already noticed.

Water-powers. The following notes of water-powers were taken at the time of this survey, in 1879.

On the Red river are the Fergus Falls flouring mills, owned by H. G. Page and George B. Wright, close below the lower bridge in Fergus Falls, having ten feet head; and George B. Wright's saw-mill, close below the upper bridge, with twelve feet head. A dam supplying fifteen feet head had also been recently built by Mr. Jacob Austin, three-fourths of a mile above the last, in the east part of the corporation of Fergus Falls. The elevation of the river near the east line of the corporation is 1,195 feet above the sea; of the pond above the saw-mill, 1,173; and close below Page & Wright's flouring-mill, 1,151. The entire fall within the corporation limits, in three miles, is nearly seventy feet. Because of the numerous large lakes on the upper part of this stream, its volume here is not greatly affected by either heavy rains and snow-melting or dry seasons. Moderate expense in the construction of dams to make Otter Tail, Rush and Pine lakes reservoirs, filled in spring several feet above their present level and drawn down in times of drought, would much increase the available water-power of the Red river at Fergus Falls and along all its extent from Otter Tail lake to Breckenridge. In this distance the river falls nearly 375 feet, averaging five feet per mile. Its bed is the hard stony clay of the glacial drift, affording a good foundation for dams, and along most of this distance the sloping river-banks permit the water to be carried in canals so as to furnish any amount of head desired for milling purposes. On the west the wheat of the Red river valley, and on the east oak, maple, ash and pine timber, invite the further utilization of the magnificent water-power of this river.

Balmoral flouring mill, on the outlet of the West and East Battle and Clitherall group of lakes, has nine feet head.

On the Pelican river are the Pelican River flouring mills at Elizabeth, with ten feet head; and R. L. Frazee's flouring mill at Pelican Rapids, with twelve feet head. Spring Creek flouring mill, in section 2, Scambler, on a tributary of Pelican lake, has fourteen feet head. The large lakes that are the sources of the Pelican river, and the descent of this stream about 200 feet from lake Lizzie to its mouth, with a channel and banks of glacial drift, make its water-power almost equally valuable with that of the Red river.

On the head-stream of the Pomme de Terre river are the Parkdale flouring mills, owned by A. Kaus & Son, in section 4, Tumuli, having twenty feet head. This power is made permanent through the summer by drawing several feet from a lake on the upper part of the stream.

Building stone. Otter Tail county has no exposure of the bed-rocks, and therefore no quarrying; but the boulders of the drift are much used for foundations, walling cellars, curbing wells, and for highway culverts.

Lime. Magnesian limestone boulders are gathered and burned for lime by M. Gelett in the southwest part of Parker's Prairie, near Fish lake; J. R. Anderson in Leaf Mountain township; Orris Albertson near Clitherall; Hans Gilbertson and Andrew Vannerstrom in sections 4 and 5, Clitherall, between West Battle lake and Turtle lake; Charles Black and Gilbert Gilbertson in Saint Olaff; J. Westover in section 2, T. 135, R. 40, near the mouth of Dead lake; James T. Thorn near Pelican lake; Mathias Halvorson, section 5, Fergus Falls; E. Barbeau and J. A. Nelson & Brothers in Fergus Falls; Andrew Wieber in Trondhjem; and Peter Carlson in the south part of Oscar; and probably by many others in various parts of the county. These lime-burners average only a few hundred barrels apiece yearly, supplying only the demand of their vicinity. Most of the large boulders of the drift are granite, gneiss and other crystalline rocks, perhaps one in twenty being limestone; but a much greater proportion of the gravel of both the modified drift and till is limestone. At Dayton bridge this makes fully half of the gravel in the till.

Bricks. Henry Asseln made 100,000 bricks in 1878 on section 19, Parker's Prairie, near Fish lake which lies only a few feet lower than where the clay was dug. Below the soil there is five feet of yellowish clay suitable for this manufacture, but farther down the clay is gravelly till of the ordinary type, extending beyond the bottom of a well twenty feet deep. Some sand was mixed with the clay for tempering. These bricks were of fair quality, sold for $7 to $10 per thousand.

In Fergus Falls bricks have been made since 1872 by J. A. Nelson & Brothers. Their product in 1879 was 600,000, bringing $7 to $10 per thousand. The clay is dug from rounded hills and swells about thirty feet above the river. Generally these hills consist of till, or gravelly clay with boulders; but sometimes this deposit, as in excavations near the court-house, is seen to contain pocket-like masses of stratified clay, extending several feet, and enclosing laminæ of sand, a sixteenth to an eighth of an inch thick. The clay dug by the Messrs. Nelson for brick-making is nearly free from gravel, but it holds occasional rock-fragments up to three inches in diameter, thought to vary in number from ten to fifty in a cart-load. No sand is added for tempering. These bricks are cream-colored, and of good and durable quality.

Another brick-yard was opened in 1879 by S. R. Childs beside the Red river three miles west of Fergus Falls and a short distance south from the mouth of Pelican river. His product in 1879 was about 200,000.

ABORIGINAL EARTHWORKS.

Rev. C. M. Terry describes a series of about a dozen artificial mounds on a high bluff between East and West Battle lakes. "They have the appearance of having been a fortified camp. Some of them are long and four to six feet wide. Others are nearly round. The largest round mound is about six feet high."

The largest group of artificial mounds observed in this county is on the south side of the Red river about fifty rods west from the mouth of Otter Tail lake. Here sixteen mounds, all having the usual dome-like form, were counted on a space extending some forty rods from north to south and about a dozen rods in width, elevated about 35 feet above the lake. One of these is ten feet high, but the others are small, varying from one to four feet in hight. The ten-feet mound and another close southeast from it, three feet high, have been partly excavated and were found to contain human bones, being burial mounds. A ravine east of these divides them from a nearly level tract some 20 feet above the lake, on which a third of a mile farther east are four mounds each three feet high excepting the most northern one, which has only half this size. A sketch map of these localities is shown in fig. 32.

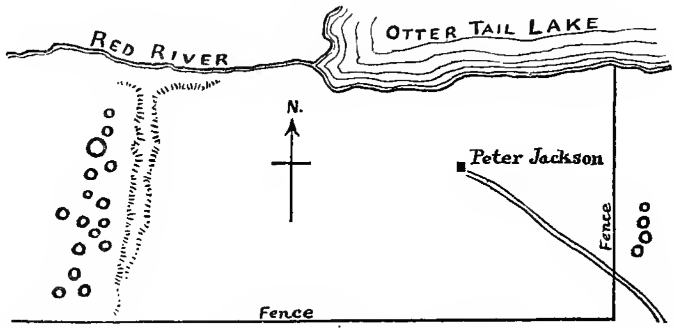


FIG. 32. ABORIGINAL MOUNDS IN SEC. 4, EVARTS, AT THE MOUTH OF OTTER TAIL LAKE.
Scale, 40 rods to an inch.

At the east end of Otter Tail lake, a sixth of a mile south from the former site of Otter Tail City, three mounds are situated a few rods east of the road, lying in a nearly north and south line, the middle one being eight feet high and the others about two feet high.

A half mile north from the site of Otter Tail City two mounds, each two or three feet high, were seen fifteen or twenty rods west from the road.

In the northeast part of Rush Lake township, in or near the south half of section 1, four mounds, two to five feet in hight, were seen beside the road, three being on its west side and one on the east, between the road and Otter Tail river.

In the N. W. ¼ of section 36, Perham, four mounds from two to three feet high were noted, lying exactly in a straight line the direction of which is N. 35° W., referred to the true meridian. They are ten or fifteen rods east of the road, and the length of the series is some twenty rods.

About a mile north from the last, a mound seven or eight feet high was seen a half mile east of the road.

Several mounds about five feet high lie on the east side of Prairie lake in Pelican township.

On the top of Indian hill in Oscar is an artificial mound forty feet long from north to south and twenty-five feet wide. Its hight is now two feet, but was probably once three feet. Two skeletons were disclosed by a small excavation in this mound.

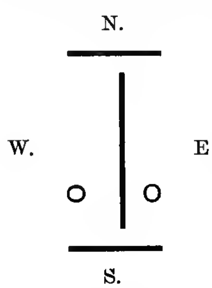
In the north part of Carlisle two hills that overlook Fish lake, above which they rise 40 or 50 feet, have each an artificial mound about three feet high on their tops. One of these is in the N. W. ¼ of the S. W. ¼ of section 3, and the other in the N. E. ¼ of the N. E. ¼ of section 5, Carlisle.

On the upper or Herman beach of lake Agassiz, about a half mile south of the Red river and near the centre of section 33, T. 132, R. 44, is a mound six feet high; and within forty rods farther south are several others one to three feet high.

Mr. J. A. Colehour and Rev. Myron Cooley, of Battle Lake, have given some attention and labor to ascertain the distribution and nature of the mounds in this county, and at the request of the state geologist Mr. Cooley has furnished the following condensed statement of what has been ascertained by them.

MOUNDS IN OTTER TAIL COUNTY.

This county is rich in mounds and relics of that prehistoric people known as mound-builders. In the townships of Everts, Girard, Amor, Perham and Star Lake, numberless mounds are found of every shape and size together with many sites of prehistoric villages. In the woods on the north shore of East Battle lake there is a group of mounds; they have never been examined and are covered with a heavy growth of timber. A few pieces of pottery have been picked up occasionally in the vicinity. At the east end of Battle lake there are scores of mounds scattered around on the bluffs south of where the outlet from East Battle lake enters Battle lake. The general plan seems to have been a great semi-circle, terminating in two large mounds about eighty rods apart facing the lake. One of these large mounds has been opened and parts of several skeletons taken out, also a curious bone chisel eight inches long and an agate knife blade two inches long. One of the smaller mounds yielded up five skeletons and a mass of flint and agate chips. At the west end of Battle lake near the outlet there is another group of mounds which seem to be very ancient, as they have been weathered down more than any of the others, and those which have been examined show nothing but bone-dust, ashes, bits of charcoal, and in one instance a fragment of coarse woven matting. One of these mounds is twelve (12) feet high, another is 75 feet long by 5 feet high. There are about a dozen mounds in this group. On a bold bluff overlooking the Red river a short distance below where it leaves Otter Tail lake, is a group of eighteen mounds; seventeen of these are small, from two and a half feet to four feet high and from twelve to twenty feet in diameter. The eighteenth mound, which stands on the highest part of the bluff, is as large as all the others put together. Several of these mounds have been partially excavated, and several skulls and parts of skeletons taken out; also some clay balls the size of medium sized marbles, some stone implements, agate knife blades and flint and agate chippings. Dead lake seems to have been a favorite haunt of these people. At two places on the south shore there have been extensive villages, and many specimens of pottery, arrow points, spear-heads, stone hammers and other utensils have been found. One of these village sites, where the Dead river leaves the lake, seems to have been protected on two sides by the lake, on the third by the river, and on the fourth by a canal cut from the lake to the river, thus practically making an island of the village site. On the north shore of Dead lake in Perham township is a most interesting group of mounds. The bluff here is densely wooded and hard maple trees 18 inches in diameter are growing on some of the mounds. The mounds here are very numerous and of great variety. The largest round mound is about 10 feet high and 60 feet in diameter. A partial examination of this mound brought to light a few agates, pieces of stone hammers, a quantity of charcoal and fragments of human bones. Directly north of this round mound is found a group in this position. The longest mound in



this group is 240 feet long by 12 feet wide and 4 to 5 feet in hight; the long mounds on the north and south are of the same width and hight but only 60 and 42 feet long respectively. The round mounds are exactly alike, about 15 feet in diameter and 5 feet high. None of these mounds have been thoroughly examined. Of the structure of these mounds all that have been excavated are similar. At a level with the surrounding surface a layer of coarse gravel is found, then a layer of sand, then more gravel, and over this a layer of black surface soil varying in thickness from 2 to 10 feet. If the mounds have been used for burial, the skeletons are in nearly every case found on the layer of sand.

There have been many other mounds reported in other parts of the county, but the places have not been visited to find if the report could be verified or not. It is safe to say, however, that Otter Tail county is as rich in prehistoric remains as any county in the state. In all cases the sand and gravel have been brought from the lake beach, and fragments of shells are frequently found in these layers.

CHAPTER XXI.

THE GEOLOGY OF WADENA AND TODD COUNTIES.

By WARREN UPHAM.

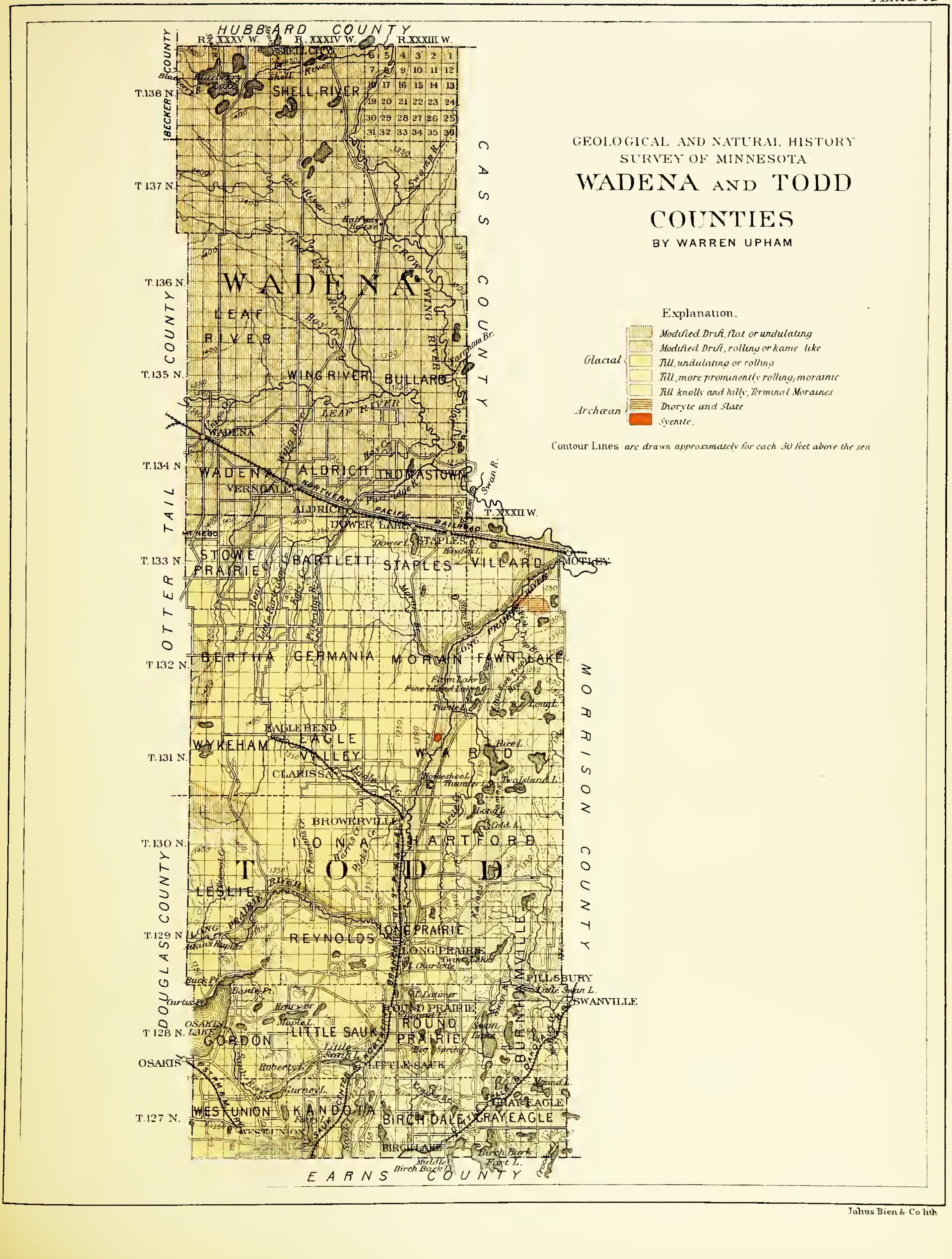
Situation and area. Wadena and Todd counties (plate 52) are in the central part of Minnesota. Long Prairie, the county seat and largest town of Todd county, is distant 105 and 115 miles, respectively, northwest from Minneapolis and Saint Paul. Wadena, the county seat and largest town of Wadena county, is 35 miles north-northwest from Long Prairie.

Wadena county has a length of five townships from north to south, and a width of three from east to west, comprising thus fifteen townships of the governmental survey. Todd county has a length of seven townships from north to south, excepting that the most southern tier of sections belongs to Stearns county, leaving Todd county forty-one miles long; and its width is four townships, or twenty-four miles. The Crow Wing river, which forms the boundary between Moran, its most northeastern township, and Cass county, sets off to the latter about four square miles that would otherwise belong to Moran, being the only deficiency from the rectangular outlines of both these counties.

The area of Wadena county is 543.63 square miles, or 347,922.43 acres, of which 8,524.62 acres are covered by water; and the area of Todd county is 1,008.34 square miles, or 645,336.72 acres, of which 27,111.58 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Each of these counties lies wholly within the Mississippi basin, and Wadena county belongs wholly to the basin of the Crow Wing river, which is the largest tributary of the Mississippi from the west above the Minnesota river. The principal branches of the Crow Wing river in Wadena county are Swamp river on the east, and Shell, Cat, Leaf and Partridge rivers


GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
WADENA AND TODD COUNTIES
BY WARREN UPHAM
Explanation.
Glacial
Modified Drift, flat or undulating
Modified Drift, rolling or kame like
Till, undulating or rolling
Till, more prominently rolling, morainic
Till knolls and hills, Terminal Moraines
Archæan
Dioryte and Slate
Syenite.
Contour Lines are drawn approximately for each 50 feet above the sea
HUBBARD COUNTY
CASS COUNTY
MORRISON COUNTY
OTTER TAIL COUNTY
DOUGLAS COUNTY
BECKER COUNTY
EARNS COUNTY
WADENA
TODD
SHELL RIVER
LEAF RIVER
WING RIVER
BULLARD
WADENA
ALDRICH
THOMASTOWN
VERNDALE
STAPLES
VILLARD
MOTLEY
STOWE PRAIRIE
BARTLETT
BERTHA
GERMANIA
MORAN
FAWN LAKE
WYKEHAM
EAGLE VALLEY
EAGLE BEND
CLARISSA
WARD
BROWERVILLE
IONA
HARTFORD
LESLIE
REYNOLDS
LONG PRAIRIE
BURNHAMVILLE
PILLSBURY
SWANVILLE
ROUND PRAIRIE
GORDON
LITTLE SAUK
OSAKIS
WEST UNION
KANDOTA
BIRCHDALE
GRAY EAGLE
BIRCH LAKE
NORTHERN PACIFIC RAILROAD
T.138 N.
T.137 N.
T.136 N.
T.135 N.
T.134 N.
T.133 N.
T.132 N.
T.131 N.
T.130 N.
T.129 N.
T.128 N.
T.127 N.
R.XXXV W.
R.XXXIV W.
R.XXXIII W.
T.XXXII W.

on the west. From Todd county the Crow Wing river receives its largest tributary, the Long Prairie river, which drains about half of Todd county, besides the northeast quarter of Douglas county. Red Eye river from the north and Wing river from the south are large affluents of Leaf river; and Long Prairie river receives Moran brook and Eagle creek from the west, and Fish Trap brook and Turtle creek from the east, besides numerous smaller streams.

In southeastern Todd county the Swan river gathers its head-waters in Burnhamville and portions of adjoining townships, flowing thence east through Morrison county to the Mississippi.

From Osakis lake the Sauk river flows east and then south through Little Sauk and Sauk lakes into Stearns county. Farther east, most of Birch Dale township and portions of Round Prairie and Gray Eagle are drained to the Sauk river in Stearns county by Adley creek.

Lakes. The southern part of Wadena county has only a few small lakes, situated mostly near the Crow Wing river; but several lakes from one to two and a half miles long lie in the north part of this county, the largest being Blueberry lake in the centre of the most northwestern township.

Osakis lake, seven miles long and from a half mile to two or three miles wide, is the largest in Todd county. Mr. Terry's description of this lake has been already given in the report of Douglas county. North and west of the Long Prairie river, Todd county has only few and small lakes, the largest being Dower lake in section 9, Staples. The half of the county south and east of this river, however, has many lakes, the largest of which, after Osakis lake, are Henry (or Maple), Little Sauk, Sauk and Fairy lakes toward the southwest, and the Birch Bark lakes, Swan, Latimer, Charlotte, Cold, Two Island, Thunder, Rice, Long and Fawn lakes toward the east.

Topography. The surface of Wadena county is almost wholly gravel and sand, belonging to the modified drift, approximately level, but usually undulating in long slopes, with the elevations 5 to 10 or 20 feet above the depressions, the average hight above the numerous streams being about 25 feet.

Todd county is more diversified. Such modified drift occupies only a small portion of its area, being chiefly confined to belts one to two miles wide next to the line between this and Wadena county, on the Crow Wing river, on the Long Prairie river, and through the western third of Round Prairie. The remainder of this county, excepting several other small tracts of modified drift, is covered by the unmodified glacial drift, called till or boulder-clay. For the greater part this has a smoothly undulating or rolling surface, with elevations 20 to 40 feet above the depressions, but on considerable tracts it is more prominently rolling and hilly, constituting terminal moraines. To the latter class belong the drift hills 50 to 100 feet high north and east of Osakis lake and reaching thence southeast to Sauk and Birch Bark lakes; hills 100 to 200 feet high, occupying most of Gray Eagle and Burnhamville townships; and their continuation northward, 50 to 100 feet high, along the east border of the county to the east part of Fawn Lake township. Near the north end of the county, a group of similar hills, 50 to 100 feet high, occurs in Stowe Prairie, culminating in Mount Nebo; and a more extensive tract of like roughly hilly surface reaches from Moran brook northeasterly into Moran township.

Along the greater part of its course northward from Long Prairie village, the valley of Long Prairie river has a width of about a mile and is bounded by moderate slopes which rise gradually to an average hight 40 to 60 or 75 feet above this stream, seldom forming the steep bluffs that indicate undermining erosion by the river; but in the west edge of Long Prairie and through Reynolds this valley is only a fourth to a third of a mile wide and is enclosed by bluffs 60 to 75 feet high, with steep slopes, while in Leslie it is bordered by irregular morainic hills.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, Saint Paul.

a. *Main line.*

	Miles from Duluth.	Feet above the sea.
Motley	137.1	1227
Summit, grade	141.2	1255
Hayden Brook, bed, 1230; grade	143.3	1243
Staples' Mills	144.6	1276
Dower Lake station (a summit)	146.6	1293
Aldrich	151.3	1327
Partridge river, bed, 1306; grade	151.5	1325
Verndale	155.3	1349
Wing river, bed, 1314; grade	156.5	1330
East branch of Union creek, bed, 1328; grade	161.0	1343
West branch of Union creek, bed, 1323; grade	161.4	1343
Wadena	161.9	1350
Wadena Junction	163.9	1352

b. *Little Falls & Dakota railroad (leased by Northern Pacific railroad).*

	Miles from Little Falls.	Feet above the sea.
Manley creek, bed, 1169; grade	18.0	1177
Summit, cutting 23 feet; grade	19.2	1259
Summit, grade and natural surface	20.8	1269
Summit, grade and natural surface	22.6	1292
Gray Eagle	25.1	1223
Prairie brook, bed, 1177; grade	27.8	1192
Birch Bark lakes, about	27.8	1175
Birch Lake station	28.6	1226
Summit, grade and natural surface	29.7	1281
Spaulding	31.1	1292
Summit, cutting 13 feet; grade	32.6	1338
Sauk river, bed, 1212; grade	36.7	1225
Sauk Center	37.0	1232

Elevations, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

a. *Fergus Falls line.*

	Miles from Saint Paul.	Feet above the sea.
Silver creek, water, 1271; grade	122.4	1280
West Union	124.5	1336
Osakis	130.4	1342

b. *Sauk Center & Northern branch.*

	Miles from Saint Paul.	Feet above the sea.
Sauk Center	117.2	1254
Hobogan creek, water, 1231; grade	117.7	1247
Ashley creek, water, 1240; grade	120.4	1258
Summit, cutting 8 feet; grade	122.0	1299
Creek, water, 1260; grade	122.8	1270
Little Sauk	126.9	1252
Sauk river, water, 1239; grade	127.0	1252
Summit, grade and natural surface	129.6	1346
Creek, water, 1295; grade	134.5	1300
Long Prairie	135.4	1298
Long Prairie river, water, 1286; grade	135.7	1293
Dick's creek, water, 1268; grade	142.8	1278
Browerville	143.0	1281
Clarissa	148.5	1331
Eagle creek, water, 1328; grade	150.1	1338
Eagle creek, water, 1345; grade	152.3	1353
Eagle Bend	153.6	1383

Approximate elevations of rivers and lakes are as follows: Crow Wing river on the north line of Wadena county, estimated 1,350 feet above sea-level, and at Motley, 1,206, two or three feet lower than at the northeast corner of Todd county, and as much higher than at the mouth of Long Prairie river; Leaf river on the west line of Wadena county, about 1,300; Long Prairie river on the west line of Todd county, estimated 1,310, at Long Prairie, 1,274, and at its mouth, 1,203; Osakis lake, about 1,310; Little Sauk lake, 1,240; Sauk lake, 1,220; and the Birch Bark lakes, 1,175.

The highest land in Wadena county is about 1,400 feet, and its lowest land, where the Crow Wing river crosses the east line of Thomastown, is about 1,225 feet above the sea. The mean elevation of this county is approximately 1,350 feet.

Morainic hills in Gray Eagle, Burnhamville and Stowe Prairie, 1,450 to 1,500 feet above the sea, are the highest points of land in Todd county; and its lowest land, the shore of the Crow Wing river at the northeast corner of Villard, is 1,208 feet above sea-level. Estimates of the average hight of the townships are as follows: Villard, 1,260 feet; Fawn Lake, 1,280; Ward, 1,320; Hartford, 1,330; Burnhamville, 1,300; Gray Eagle, 1,275; Staples, 1,320; Moran, 1,280; Long Prairie, 1,325; Round Prairie, 1,300; Birch Dale, 1,275; Bartlett, 1,380; Germania, 1,400; Eagle Valley, 1,360; Iona, 1,360; Reynolds, 1,360; Le Sauk, 1,325; Kandota, 1,280; Stowe Prairie, 1,400; Bertha, 1,410; Wykeham, 1,400; Leslie, 1,360; Gordon, 1,330; and West Union, 1,310. The mean elevation of Todd county, derived from these figures, is approximately 1,330 feet.

Soil and timber. The soil of Wadena county is sandy and gravelly, but under cultivation it shows a good degree of fertility. Pinus Banksiana, Lambert, commonly called "jack pine," growing with straight trunks forty to fifty feet high, covers most of this county with a rather open and scanty forest, in which there is comparatively little underbrush, the ground being carpeted with grasses, sedges, low blueberries, bearberries and aromatic wintergreen. In exceptional situations, as along streams and about lakes, more dense timber occurs, including red and white pines, black spruce, balsam fir, tamarack, bur and white and black oaks, sugar and white maples, box-elder, white and red elms, black and green ash, wild plum, wild black and red cherries, sheep-berry, ironwood, canoe birch, and poplars. Basswood and cottonwood are found infrequently with the foregoing, being most plentiful southward. Mountain ash, limited to the north part of the county, attains a diameter of six inches. Among the shrubs that grow in these situations are the frost grape, Virginian creeper, climbing bitter-sweet, smooth sumach, prickly ash, hazel-nuts of two species, choke-cherry, red raspberry, species of thorn, wild roses, prickly and smooth gooseberries, black currant, species of cornel, wolfberry, high bush cranberry, low birch, hoary alder, and willows.

Todd county has for the most part a very productive clayey soil, which bears a heavy growth of timber, usually with much underbrush, the list of the trees and shrubs being nearly the same as that just enumerated. The general southwestern limit of the evergreen trees, namely, the pines, spruce and fir, and of blueberries and wintergreen, is approximately at a line drawn diagonally from the northwest to the southeast corner of this county; but minor irregularities in the course of this line cause it to cross the county in a nearly east to west course, from the north part of Burnhamville to the north part of Leslie. The jack pine reaches a few miles farther southwest than the white pine. The former grows preferably on sandy and gravelly land, and the latter on clayey soil. Much white pine of large size occurs in Germania and eastward to Moran brook, and in Fawn Lake and the east township of Ward.

Prairies a few miles in extent occur in the south part of Wadena county, reaching southward on the east side of Wing river into Stowe Prairie township in Todd county; and on the north side of the Shell river a prairie extends from the edge of Shell River township about eight miles northward into Hubbard county.

Long prairie borders the river of this name some twenty miles, with an average width of about one mile, from lake Charlotte and Long Prairie village north to the west line of Fawn Lake township. It is in part level alluvium and in part sand and gravel of the modified drift, the latter mostly with a somewhat undulating surface in long slopes, its higher portions being 10 to 20 feet above the depressions. Like most of the tracts called prairie in Wadena county, this is mainly covered with scattering hazels, dwarfed oaks and other shrubs, having little clear grass land.

Round prairie, about five miles long from north to south and two miles wide, in the western third of Round Prairie township and the east edge of Little Sauk, is a grassy prairie, mostly without tree or bush, composed of similar modified drift, nearly level, excepting toward its south end where it is quite rolling with elevations 10 to 25 feet above the numerous enclosed hollows. Pleasant prairie, a mile in diameter, lies a little farther southeast in the south edge of Round Prairie township, on the east side of Big Spring or Prairie brook.

The northeast boundary of the great prairie region of southwestern Minnesota crosses the southwest corner of Todd county, and includes sections 31 and 32 and parts of adjoining sections in Gordon, nearly all of West Union, and the south edge of Kandota. From the higher parts of West Union, an extensive view of limitless prairie is seen toward the south and southwest.

GEOLOGICAL STRUCTURE.

Archæan rocks. Wadena county has no outcrop of the bed-rocks and they are exposed at only two localities in Todd county. These are in the townships of Moran and Ward.

In the channel of the Long Prairie river at the mouth of Fish Trap brook and for a third of a mile along this brook next above its mouth, being in the west part of section 34, Moran, five miles southwest from Motley, are extensive outcrops of dark and tough, nearly black dioryte, resembling that found at "the point," about a half mile south of Little Falls in Morrison county. It is a very compact, coarsely crystalline rock, with no lamination or apparent tendency to split more readily in one direction than another. Some of the large blocks of this stone, lying in the bed of the Fish Trap brook near E. P. Jones' mill, which is an eighth of a mile above its mouth, ring sonorously like an iron kettle when struck by a hammer. This rock forms ledges one to four rods long, rising one to five feet above the water, in the channel of Long Prairie river and in both its banks at the mouth of this tributary, and at a few places for six or eight rods distance both above and below. Its outcrops along Fish Trap brook are seen at many places to Jones' mill, but above this for about a quarter of a mile are mostly covered by the mill-pond. Farther above, it has no exposure along this brook, which flows over glacial drift with many boulders and frequent rapids. In the vicinity of the mill its ledges occupy a width from two to four rods, and rise about twenty feet above the brook. It is mostly divided by joints from two to ten feet apart; but when Mr. Jones built his dam, he reports that he uncovered an extent of thirty feet of it without a seam. This rock is wholly worthless for quarrying because of its toughness to drill, and more especially because of the difficulty to bring it into any desired dimension. It is very hard to fracture and is evidently very durable.

Frequent outcrops of this rock, of small extent and hight, are reported within the next two miles eastward, in sections 34 and 35 and in the S. W. ¼ of section 36, also probably reaching across the township line, into the edge of the sections next south. Mr. Jones, who has explored this district, thinks that the only exception from the character of the rock as described, is a small belt seen at the east side of Fish Trap brook, extending from the lumbermen's dam at its mouth a distance of about ten rods along the east shore of the pond. Here a nearly black slate is exposed, having its cleavage vertical or differing from this within a limit of five degrees upon each side. Its strike is N. 55° W., being parallel with the brook. The width of this slate visible is only from five to fifteen feet, and its contact with the neighboring dioryte is not seen.

The second locality of outcropping rock is ten and a half miles farther southwest, lying nearly at the centre of the N. E. ¼ of section 15, T. 131, R. 33, the west township of Ward. It is on land of Joseph Woell, a third of a mile west of Long Prairie river, and an eighth of a mile east of the road from Motley to Long Prairie, which here runs on the west edge of the valley-plain of modified drift and alluvium. The extent of this ledge is some twenty rods from northwest to southeast, with a width of three or four rods, including several exposures, the longest of which reaches about a hundred feet. Their hight is from four to eight feet above the plain, which is about fifteen feet above the river. This rock, mostly quite uniform, in composition, color, and texture throughout this area, is a bright-colored, medium-grained, gray syenite; containing about equal amounts of quartz, whitish feldspar, and dark, nearly black hornblende; with a somewhat smaller proportion of a light-green mineral (probably epidote), in rather smaller grains than the foregoing. This seems to be the same mineral with that seen in the rock of Cass county, five miles northwest of Motley, and it is present as a principal ingredient of the rock in Ashley, Stearns county; but it has not been noted in other outcrops of these crystalline rocks. The whole ledge here has this mineral in nearly equal amount, the only exceptions being very rare concretions, one to two inches long and thin, composed of a dark-greenish micaceous mineral, and very rare seams or veins, a sixteenth to an eighth of an inch wide and a few feet long, composed of the light-green mineral which is generally disseminated through this rock. The only other vein or variety noted was a mass of coarsely crystalline, flesh-colored feldspar, exposed upon a patch of only about one foot, but probably forming part of a long vein, adjoining which the rock was more jointed and coarse-grained than ordinary. This ledge is generally intersected by nearly vertical joints, from two or three to eight feet apart. It has never been quarried, but will probably be found valuable for common masonry; and dimension stone, six to eight feet long, could be readily obtained. Though nowhere obviously schistose, the grains of this rock are all slightly prolonged in parallelism with each other.

Glacial and modified drift. The surfaces of the rock-outcrops just described are smoothly planed and rounded by glaciation, but their striæ have been effaced by weathering.

The average thickness of the drift in these counties is probably from 100 to 150 feet. Its topographic features and material have been stated in an earlier part of the chapter; leaving the conditions of its deposition, and the glacial movements indicated by these drift deposits, to be noticed here.

Excavations in the till of Todd county generally show that the gravel which it contains is in considerable part, sometimes as much as one third, limestone; but limestone boulders on the surface are quite infrequent, probably not one in two hundred, excepting in the southwest part of the county, where in West Union and the southwest portions of Leslie, Gordon and Kandota, they are plentiful, making a tenth or twentieth part of the superficial boulders. The region from which the limestone was brought by the ice-sheet, lies on the northwest, the nearest outcrops of this rock being in Manitoba; so that it seems to prove the ice-flow to have come largely from the northwest when the greater part of the till was deposited, followed at the last by an ice-flow that came mainly from the north and northeast, bringing scarcely any limestone, its boulders more abundant than in the till from the northwest, being only granite, syenite, gneiss, crystalline schists, slate and trappean rocks, such as occur in place in the region from the lake of the Woods to lake Superior.

These observations accord with the interpretation, which is given in this and other chapters, of the belts of morainic drift as accumulated on the margin of the ice-sheet during pauses in its final retreat. When this ice-sheet of the last glacial epoch attained its greatest extent, and while its earlier moraines of recession were being accumulated, the ice-current upon this district was doubtless from the northwest and north, being confluent a little farther east with an ice-current that came from the region of lake Superior on the northeast. In seven preceding stages of the glacial recession the gradual diminution in area of the Minnesota lobe of the ice-sheet is shown, till this lobe, which at first reached from the Red river valley to Des Moines, was contracted to comparatively a very small area, extending from the Leaf hills northward through Becker county and bounded on the west by the eighth or Fergus Falls moraine in its course from lake Christina and Fergus Falls northward to Detroit and the White Earth agency. The course of the moraines marking the glacial boundary at this time shows that the ice-flow from the northwest could no longer extend across Becker, Otter Tail, Wadena and Todd counties, but that in its place the ice-flow on this district came, during the time of the Fergus Falls and Leaf Hills moraines, from the north and northeast.

At the time of the seventh or Dovre moraine the southwest border of the ice flowing from the north accumulated a distinct belt of morainic drift which crosses southwestern Todd county, entering it from Spruce Hill township in

Douglas county, passing through the west half of Leslie to Battle point on the east side of Osakis lake, and thence southeast through Gordon and the southwest corner of Little Sauk to sections 9 and 15, Kandota, beyond which it forms a hilly tract east of Sauk lake, continuing southeastward into Stearns county, but reaching on its north side into Birch Dale and Gray Eagle, where it is probably blended with the next.

At the time of the eighth or Fergus Falls moraine, this portion of the glacial margin had retreated only a few miles; but on the east side of Todd county a much greater recession had taken place, withdrawing the ice-front from northeastern Stearns county to the vicinity of lake Alexander in northern Morrison county. The southern limit of the ice-sheet in Todd county at this stage is marked by a morainic belt a few miles northeast from the preceding in southwestern Todd county, its course being from Spruce Hill through the north and east part of Leslie, southeastward by Henry or Maple lake to Little Sauk and Cedar lake, eastward through Birch Dale and Gray Eagle, and northward through Burnhamville, the east townships of Hartford and Ward and the east part of Fawn Lake. Thence it turns eastward and southeastward to lake Alexander, Fort Ripley and Little Falls, beyond which it passes to the northeast, forming in Morrison county a loop convex toward the south, similar to its loop in Todd county.

By the next recession of the ice to its ninth or Leaf Hills moraine, though its margin continued almost without change at the Leaf hills in Otter Tail county, most of Todd county was uncovered and the ice-front fell back to its northern tier of townships, there accumulating prominent morainic hills in Stowe Prairie and on Moran brook.

This glacial recession was attended by the formation of extensive kame-like deposits along the west side of the eighth or Fergus Falls moraine in Burnhamville, Hartford and Ward. The most southern portion of this tract observed is in the east half of sections 24 and 25, Long Prairie, where moderately undulating gravel and sand occupies a width of a third of a mile next west of the Twin lakes. Northward this tract increases in width to about two miles in the northwest corner of Burnhamville and the south edge of Hartford, and is called the "pine ridges" or "barrens," being covered by jack pines and small black and bur oaks. It consists of short ridges, knolls and hills of gravel and sand, sometimes with numerous boulders, rising 25 to 100 feet above the many small marshes and lakelets that are enclosed in the hollows. It continues through sections 20, 17, 8 and 5, in the east township of Hartford, passing the east end of Cold lake, and reaches half-way through Ward, where it borders the east side of Thunder and Rice lakes. In this extent of seven miles forming the north half of this tract, its average width is about one mile, and its knolls, hillocks and short ridges, trending commonly from north to south, are 25 to 50 feet high, consisting of sand and coarse gravel, with water-worn cobbles up to a foot in diameter, occasionally also enclosing larger boulders. About four miles farther north a distinct osar, or steep-sided and narrow-topped ridge of gravel and sand, about 50 feet high and a mile long, is reported by Mr. R. O. Sirrine, extending from the west side of Pine Island lake in section 31, Fawn Lake township, west to the highway.

The modified drift of Round and Long prairies, described on a preceding page, and another area of flat or moderately undulating gravel and sand that reaches from southeastern Otter Tail county into the west edge of Bertha and Wykeham and to the head of Eagle creek in the north part of Leslie, were also deposited during this glacial recession from the Fergus Falls to the Leaf Hills moraine.

A very great retreat of the ice-sheet ensued when it was withdrawn from the Leaf hills and northern Todd county to its tenth or Itasca moraine, which is conspicuously exhibited in a broad belt of drift hills that extends from north to south by the east side of lake Itasca and thence bends to the east, passing north of Fish Hook lake and south of Leech lake. Most of the area in Becker, Otter Tail, Hubbard and Wadena counties lying between the Leaf Hills moraine and the Itasca moraine is overspread by modified drift, consisting of flat or moderately undulating gravel and sand, deposited by the floods discharged from the surface of the melting and retreating ice, in the lower part of which this material, besides much clay and many boulders, had been held. These beds of modified drift were carried by the glacial streams to the border of the receding ice-sheet and deposited upon the till or boulder-clay, the upper part of which had been contained in the ice like the gravel and sand, being the part of the ice-held drift that was not removed by these streams. The thickness of the stratified gravel and sand thus spread over the till in Wadena county usually varies from a few feet to 25 or 50 feet, or perhaps more in some localities; but occasionally the till rises quite to the surface, and it is often reached by wells and exposed in the banks and beds of streams, which are then strewn with frequent boulders.

Silicified wood. Several fine specimens of silicified wood, from a few inches to two feet long, were found near together in the till by Mr. E. F. Chase about a quarter of a mile west of West Union depot. These are the largest pieces of silicified wood that have come to my knowledge as occurring in the drift in Minnesota, though small fragments have been found in many places through the west half of the state. Their source was doubtless more than a hundred miles distant northwestward, probably in Dakota, where such petrified wood abounds. Their occurrence agrees with that of the drift limestone, and with striæ noted in western Stearns county, along the Minnesota river and farther south to Cottonwood county, proving that the west part of Minnesota was covered by ice flowing southeastward from the region of the Red river and lake Winnipeg.

Alluvium. The flat tract of gravel, sand and fine silt or clay, bordering the Long Prairie river most of the way from the village of Long Prairie to its mouth, with a width varying from a half mile to one mile, having a hight only 5 to 15 or 20 feet above the river, is alluvium deposited by the stream in its stages of flood since the ice age. Outside this alluvial tract, a considerable part of the belt called the Long prairie is modified drift, usually undulating 10 to 20 feet in long and smooth slopes and elevated 20 to 40 feet above the river.

Ice-formed ridges of gravel and sand, a few feet high and three to six rods wide, were observed on the west side of lake Charlotte in Long Prairie, extending a half mile between the lake and a marsh; and on the northwest side of Osakis lake, extending some three miles from Curtis point in the east part of section 7, Gordon, westward to Worden's point in Douglas county. These were noticed because in each case roads lie on them. Such ridges are doubtless frequent on the shores of nearly all the lakes in this region, where they are bordered by marsh or low land. In part they are due to ordinary wave action, but in larger degree to ice, pushing these materials from the shallow lake-bed to the shore, as is often shown by the presence of large boulders in these ridges evidently so transported from the basin of the lake.

Wells in Wadena county.

Thomastown. F. L. Handerson; N. E. $\frac{1}{4}$ of sec. 8: well, 22 feet; soil, $1\frac{1}{2}$; sand and gravel, holding pebbles up to two or three inches in diameter, all the way below; water in large supply, abont two feet deep; a boulder fully four feet in diameter, found in the bottom of this well, was doubtless lying on till.

Aldrich. Wells in Verndale are 10 to 25 feet deep, all gravel and sand below the dark soil, which has a thickness of two feet; digging can go only about 15 feet, because of inflowing water, but driven or bored wells often go deeper, all obtaining water in abundance.

Wadena. Wells in this village and township are 15 to 20 feet deep, all the way in modified drift; water abundant and excellent. In the village the section is commonly soil, 2 feet; fine yellow sand, 1 foot; soft, laminated yellow clay, 2 to 5 feet, sometimes wanting; and sand and gravel below, usually growing coarser downward to water. On undulating tracts, where the gravel is coarser than on the flat land, its largest pebbles are three to four inches in diameter.

Wing River. William Robinson; sec. 10, at Cook's steam saw-mill: well, 14 feet; black soil, 1 foot; sand and gravel all the way below, to water.

Leaf River. A. Amidon; S. E. ¼ of sec. 25 in the south township: well, 42 feet, probably the deepest in this county; soil 2; sand and gravel, 20; dark bluish till or boulder-clay, very hard, picked, 10 feet; and yellowish gray sand below, with layers of gravel and of quicksand, 10 feet and continuing deeper; water two or three feet deep.

Shell River. Driven wells in Shell City go 25 to 35 feet, all in sand and gravel.

Wells in Todd county.

Staples. At the depot wells go 12 to 15 feet in sand and gravel, finding plenty of water. This modified drift is coarsest below, where it contains cobbles up to six or sometimes ten inches in diameter.

I. N. Clemans; N. E. ¼ of sec. 10: well, 10 feet; soil, 1 foot; hard clay, perhaps till, 9 feet and reaching deeper, enclosing layers of sand and gravel one to three inches thick; water comes from one of these seams at the bottom, filling the well half full.

Ward. R. O. Sirrine; S. E. ¼ of sec. 10 in the west township: well, 19 feet; black soil, 1 foot; all caving sand and gravel below. This is on the plain of valley drift bordering the Long Prairie river. In other parts of this township wells are 15 to 30 feet deep in till, which is yellowish in its upper portion and dark bluish below.

Hartford. The wells are nearly as in Ward, being till except a belt of sand and gravel on the Long Prairie river.

Burnhamville. Wells in Pillsbury village are 10 to 20 feet deep, all stratified gravel and sand. Excepting narrow tracts of modified drift or alluvium along streams, the wells of this township are till, like the following.

Virgil Barnes; S. E. ¼ of sec. 30, T, 129, R. 32: well, 55 feet; soil, 1; yellow till, spaded, 7; dark bluish till, much harder, but yet spaded, 43 feet, containing a layer of quicksand about a foot thick nineteen feet below the surface, with water seeping from it but failing in a dry season; beneath the till this well went 4 feet into sand and fine gravel, which continued lower; water in three or four hours rose five feet above the top of this bed.

Long Prairie. Chandler, Fisher & Waits' store; on the top of a hill in the east part of the village: well, 50 feet; soil, 2; yellow till, 12; and blue till, easier to dig than the yellow till, 36; water rose twenty-five feet from quicksand at the bottom. Other wells in the southeast half of the village are 10 to 35 feet deep in till; but on its north and west borders they are 15 to 20 feet deep in stratified sand and gravel.

Floyd Lawson; sec. 32: well, 20 feet; soil, 1; yellowish gravelly clay, 3; interbedded sand and coarse gravel, with cobbles up to one foot in diameter, 16 feet, to water.

Round Prairie. A. T. Tracy; N. W. ¼ of sec. 17: well, 25 feet; soil, 1½; a layer of very hard clay with intermixed gravel, 6 inches; and sand and fine gravel, 23 feet.

C. S. Hamlin; S. E. ¼ of the S. W. ¼ of this sec. 17: well, 30 feet; soil, 2; yellow till, picked, 28; water seeps.

Bartlett. J. B. Kelly; N. W. ¼ of sec. 6: three wells each 16 feet deep, on a level plain of modified drift which stretches northward into Wadena county; black soil, 2; an iron-rusted layer, about 1 foot; and yellowish gravel and sand, 13, becoming finer downward; water abundant, of excellent quality, as it is through all this district.

Germania. August Luehke; S. E. ¼ of sec. 4: well, 36 feet, in yellow till succeeded below by dark bluish till; water seeps, an ample supply.

School-house at the middle of the south side of sec. 5: well, 20 feet; soil, 2; yellow till, picked, 17; sand, 6 inches; and yellow till again beneath; in a few hours water rose five feet from the sand.

John J. Egly; north part of sec. 6: well, 29 feet; soil, 2; yellow till, mostly picked, 22; and dark till, about the same as the preceding in hardness, picked, 5 feet and continuing deeper; the only sand and gravel found were in cylindrical, nearly level veins, described in size as "like a man's arm;" no water was found, and this well was given up. Only about two rods from this, a well 12 feet deep is soil, 2; yellow till, 8; and sand, 2 feet, yielding an ample supply of water, underlain by yellow till.

Eagle Valley. Wells in Clarissa village, on a plain of modified drift bordering Eagle creek, are 15 to 20 feet deep in stratified gravel and sand. Other portions of this township are till.

Reynolds. William Freeman; N. E. ¼ of sec. 5, T. 129, R. 34: well, 30 feet; soil, 2; sand and gravel, 8; and till, yellow above and blue below, picked, 20; water rose from the bottom, filling the well half full. This is on the north edge of the alluvial belt of Long Prairie river, at the foot of a bluff about 40 feet high, which is composed of till, as is also the whole township, excepting narrow bottomlands along the streams.

Little Sauk. Julius Goodwater; sec. 27: well, 22; soil, 1; yellow till, 10; blue till, 11; water seeps.

Kandota. Olavns Hendrickson; sec. 21: well, 22; soil, 1, yellow till, picked, 7; gravel, 3; and again again yellow till, 11 feet; water rose slowly five feet from sand at the bottom.

Stowe River and *Bertha.* Most of the wells in these townships are 15 to 30 feet deep, in till.

Leslie. The following wells are in the south half of Leslie. William Beach; in Clotho, N. W. ¼ of sec. 1, on the alluvium of Long Prairie river: well, 16 feet deep, all gravel and sand to water.

John W. Brown; N. E. ¼ of sec. 15: well, 26 feet; soil, 2; yellow till, spaded, 3; gravel and sand, 1 foot; yellow till, very hard, picked, 8; fine, white sand, 6 inches; coarse gravel, 1½ feet, containing pebbles up to three or four inches in diameter; and blue till, very hard, picked, 10 feet and continuing deeper; water came from sandy streaks in the blue till, rising about ten feet. Owing to the decay of wooden curbing, the water in this well, though at first good, became too offensive in smell and taste to be used.

Allen W. Curtis; N. W. ¼ of sec. 28: well, 15 feet; soil, 2; yellow till, partly very hard, requiring to be picked, 12; and gravel, 1 foot, from which water rose four feet.

Gordon. A. D. Cram; on the southeast shore of Osakis lake, two miles east of Osakis: well, 28 feet; soil, 2; yellow till, spaded, 8; much harder blue till, picked, 4 feet, and bored below to the amonnt in both of 18 feet; from sand at the bottom water rose in two hours to a permanent level two feet below the surface, which is about ten feet above the level of Osakis lake only a few rods distant. This well and numerous others in this township, though having good water at first, are disused because of the contamination of the water by decaying wood curbing.

Ole Johnson; sec. 28: well, 20; soil, 2; yellow till, 17; water rose two or three feet from gravel which was dug into one foot and extended deeper.

West Union. S. M. Herbert; N. W. ¼ of sec. 23: well, 43 feet; soil, 1; yellow till, picked, 10; blue till, less gravelly and softer, readily spaded, 19; sand, 2; and again similar blue till, 11; water rose several feet from quicksand at the bottom.

H. M. Judd; S. W. ¼ of this section 23: well, 25 feet; soil, 1; yellow till, picked, 10; softer blue till, as in the foregoing well, dug 12 feet and bored 2 feet lower, when the anger fell and water rose about five feet.

MATERIAL RESOURCES.

Agriculture is the leading industry and resource of this district; and its good supply of timber places the production of lumber and wooden manufactures next.

Water-powers in use at the time of this survey in 1881 were as follows:

Verndale flonring mills, E. M. Britts & Co., on the Wing river near the centre of section 18, Aldrich, one and a half miles north of Verndale; three run of stone; head, about twelve feet. This dam is founded on the till, which is covered here by ten feet of sandy and gravelly modified drift.

Good water-power is also available on the Shell river at Shell City, and at numerous points on the Crow Wing river and its other tributaries in Wadena county.

Fisher Brothers' saw-mill on the Wing river in the north part of section 5, Bertha; head, six feet; sawing basswood, oak, poplar and white pine, the last being mostly hauled from Germania township.

John D. Nickey's saw-mill on Eagle creek in the N. E. ¼ of section 36, Eagle Valley; head, ten feet, flowing back three-fourths of a mile; sawing oak, basswood, poplar and birch, but scarcely any white pine. The last occurs scatteringly here and for two miles southeastward to Dick's creek; but it is not found farther west along Eagle creek.

Mathias Brown's saw-mill on Dick's creek in the southwest edge of section 8 of the west township of Hartford; head, about ten feet; sawing basswood, oak, poplar, ash and white pine, the last being mostly hauled from the east part of Hartford.

E. P. Jones' saw-mill on Fish Trap brook near its mouth, in section 34, Moran; manufacturing pine lumber and shingles; head, nine feet.

Besides this mill-dam, three dams are built on Fish Trap brook to supply water for floating or "driving" logs from where they are cut on its upper waters into the Crow Wing river, by which and the Mississippi they are brought to the saw-mills in Minneapolis. These dams are at the mouth of the brook, with head of six feet; in the west part of section 24, Fawn Lake, with head of five or six feet; and some three-fourths of a mile above the last, in the north part of section 25, also about six feet.

Several dams of similar hight are also built for lumbering purposes on Moran brook.

James Hart's saw-mill on Turtle creek in the S. W. ¼ of section 6 of the east township of Ward; sawing mostly white pine, which is cut in this township and Fawn Lake; head, nine feet.

Long Prairie flouring mill, Chandler, Fisher & Wait; on the northeast or left side of Long Prairie river, in the west edge of section 18, Long Prairie, nearly two miles west from the village; three run of stone; head, seven feet, flowing back one and a half miles.

At this place also, on the southwest bank of the river, is a saw-mill, of the same ownership, manufacturing lumber of basswood, oak, ash, maple, elm, tamarack and white pine, the last being hauled to the mill from the east part of Hartford.

Little Sauk flouring mills, McNiece Brothers & Carpenter; three run of stone; head, twelve feet, flowing the Sauk river back eight miles, through three lakes, the two western of which were Roberts lake, in the southwest part of Little Sauk, and Gurney lake, in sections 1 and 12, West Union, originally separated by areas of marsh, now as united called Little Sauk lake.

West Union flouring mill, A. J. Haney; on the Sauk river in the southeast corner of section 3, West Union, a mile west of Gurney lake; three run of stone; head, eighteen feet, flowing back only about sixty rods, making a pond of five acres.

Daniel Burnham's saw-mills, sawing and planing lumber and making sash and doors, besides a grist-mill; on the Swan river in Pillsbury, Burnhamville; head, eight feet, flowing Little Swan lake, one mile long.

Bear Head saw-mill, Batchelor Brothers; manufacturing lumber and shingles; on the Swan river in the south part of section 33 of the north township of Burnhamville; head, eight feet, flowing the stream back two and a half miles to Swan lake, which is raised one and a half feet by this dam.

Building stone. No quarrying has been done in the rock-outcrops of this district, but the syenite in Ward seems worthy of it. Boulders are much used for ordinary rough masonry.

Lime. Magnesian limestone boulders are burned for lime by John Bail in section 18 of the south township of Leslie; by J. C. Stone and David Lane and his sons, in the southwest part of Gordon, Mr. Stone's supply of boulders being gathered mostly from the shores of Osakis lake; and by Joseph Jordan, Byron King, D. W. Phelps and George R. Virgin, in West Union. Most of these average only 50 to 100 barrels each, or one kilnful, yearly; supplying the needs of themselves and neighbors. The usual price is $1.25 per barrel. The largest blocks found weigh two or three tons. About a fourth part of the lime is brown, like that of the Shakopee limestone, while the remaining three-fourths are white lime.

Bricks. In the S. W. ¼ of section 8, Stowe Prairie, seven miles south of Wadena, brick-making was begun in 1881 by Murray & Allen, their product that year being 80,000, sold in Wadena for $11 per thousand. These are red bricks of fair quality, made from stratified clay, to which an eighth part as much sand is added for tempering.

Attempts to make bricks by Frank and Joseph Ward in the S. W. ¼ of section 10, Stowe Prairie, in 1879 and 1880, failed on account of the limestone particles in the clay (till), by which the bricks were cracked after burning.

In the north part of Moran bricks were first made in 1880 by Mealey & Staples on the south side of the railroad about a half mile east of Hayden brook and lake, or nearly two miles east of Staples depot. About 75,000 red bricks of fair quality were made there.

In 1881 H. B. Morrison of Motley opened a brick-yard three-fourths of a mile farther east, on the north side of the railroad near the middle of section 18, Moran, five miles west of Motley, producing red bricks of bright color and of excellent quality as to strength and durability. His product in 1881 was about 450,000, selling at $8 to $10 per thousand, loaded on the cars. Wood for fuel costs $2 per cord. Sand, obtained within a short distance, is mixed with the clay for tempering, in the proportion of one to five. Next below the soil is yellowish gray, laminated clay four feet thick, used for the brick-making, found to extend over a large area, probably a mile square; and this is underlain by sand and gravel, in which a well here gets water abundantly at the depth of fifteen feet.

Near the centre of section 35, Eagle Valley, two miles southeast from Clarissa, brick-making was begun in 1880 by George G. Howe. His product in 1880 was 80,000, and in 1881 about 125,000, selling at $8 per thousand. They are of good, durable quality, and are cream-colored, excepting near the outside of the kiln where their color is reddish. Mr. Howe also makes curved bricks for wells, at $10 per thousand. The clay used is gray, levelly stratified, exposed by the excavation to a depth of five or six feet. It contains limy concretions in some parts, which are therefore rejected. No sand is added. This locality is in the valley of a little brook, the slopes which rise near on each side being ordinary till.

Red bricks were made by John Zennder some ten years ago about a mile west of Long Prairie village, in the S. W. ¼ of the N. E. ¼ of section 19, and also on his farm two miles southeast from this village. They were made from the till or boulder-clay, and were of poor quality, being cracked by particles of lime due to the limestone gravel in the till.

William Hartung in 1878 made red bricks for building his house, in the N. W. ¼ of section 9, Birch Dale.

A kiln of dark red bricks was made about eight years ago on land of L. S. Bishop in the S. E. ¼ of the N. E. ¼ of section 23, Birch Dale, close north of the Middle Birch Bark lake.

Brick-making was begun in 1881 by Pangburn & Moore on the east shore of Sauk lake in the south edge of section 26, Kandota, three miles northeast from Sauk Center, where their product of bricks is chiefly used or sent away by rail. Their excavations are forty to seventy rods north of the county line. The clay-bank rises steeply from the water's edge to a hight of 15 to 20 feet, and from its top a level surface extends back ten to twenty rods, which is the width of the stratified clay. The surface farther east is rolling till, which also seems to form the opposite shore, about two-thirds of a mile distant. At the south end of the most southern excavation the black soil is directly underlain by a bed of yellowish gray clay about ten feet thick; next is a bed of yellowish sand, about 5 feet thick, exposed along a distance of four or five rods; and under this is clay like that above. In both these clay deposits occasional limy concretions are noticeable, forming little irregular sheets, an eighth to a quarter of an inch thick and one to four inches broad, embedded in horizontal position. In the northern part of this excavation, which extends in all about fifteen rods, the whole thickness of twenty feet from the lake-level to the top of the bank is levelly bedded clay, mostly weathered to a yellowish gray color. Some of the concretionary sheets before mentioned were also seen in this portion. Farther north, an excavation ten rods long is also wholly clay. Here its lower part contains many cylindric ferruginous concretions, reminding one of limbs and twigs of trees, films of iron-rust being arranged in the clay in the concentric manner of the rings of the growth in wood. In the upper ten feet of this excavation, above these concretions, the clay is very distinctly and finely laminated, and includes occasional ferruginous laminæ up to a third of an inch thick, also laminæ of coarse sand up to a fourth of an inch thick. A bone six inches long, bearing marks of gnawing, was found in this northern excavation about ten feet below the surface, being the only fossil detected here. This clay was probably deposited in a channel melted out from the surface of the ice-sheet at its thinned margin, while ice yet filled the hollow in which Sauk lake lies. The bank newly undermined by the lake at several places within a half mile to the north consists of clay somewhat laminated horizontally, but containing considerable gravel and here and there stones as large as a foot in diameter, being perhaps a subglacial deposit. The amount of clay free from gravel and adapted for brick-making is sufficient for extensive work many years. The bricks are cream-colored, excepting near the outside of the kiln where they are red. No addition of sand is needed for tempering.

Springs. A half mile northeast from Wadena, on the east branch of Union creek in the S. W. ¼ of section 5, are "sulphur springs," whose water possesses cathartic properties.

Cool springs of excellent water occur at Shell City.

On the east shore of Sauk lake, about a half mile north from Pangburn & Moore's brick-yard, a large chalybeate spring issues only twenty feet from the lake, to which it pours a stream a foot wide and three inches deep. It is on land of Aaron Doty, in section 26, Kandota.

The "Big Spring" which forms the source of Big Spring creek or Prairie brook, in the S. W. ¼ of section 20, Round Prairie, is situated on the west border of a large tamarack swamp, and is some ten rods east from the edge of the Round prairie, the surface of which averages about 25 feet above this spring. It is a basin of very clear water, forty or fifty feet long from east to west, twenty feet wide, and three to six feet deep. A sluggish stream, four feet wide and six inches deep, flows from it. No irony sediment is seen here.

ABORIGINAL EARTHWORKS.

Mr. O. E. Garrison, in the account of his canoe journey on the Crow Wing and Mississippi rivers published in the ninth annual report of this survey, gives the following note of aboriginal earthworks in Wadena county. "In section 3, T. 136 N., R. 33 W., on the left bank of the Crow Wing river near the head of a rapids are two ancient mounds. I landed and made the following rough measurements. The one nearest the river is fifty-six paces from the top of the river-bank, here about twelve feet high; its longest diameter is nearly parallel with the course of the stream; the shape is oval, the longer diameter being forty-five feet, and the hight four feet. The second mound is thirty-three paces farther west, having about the same size and direction as the first, but is somewhat higher. North of both is a depression as if the earth had been excavated in making them. The soil is sandy with no boulders, except in the river channel where they are large and numerous."

Five mounds of the usual dome-like form, five to seven feet high, arranged in a somewhat quincuncial group, the central one being the largest, with a distance of about a hundred feet from it to each of the others, lie on Ole Swanson's land, in the N. E. ¼ of section 4 of the south township of Burnhamville, ten or fifteen feet above Little Swan lake and nearly a fourth of a mile from its shore.

About a half mile farther north, in section 33 of the north township of Burnhamville, several aboriginal mounds one and a half to two feet high occur on land of C. D. Batchelor on the north side of the road some fifty rods northeast from the Bear Head mill.

CHAPTER XXII.

THE GEOLOGY OF CROW WING AND MORRISON COUNTIES.

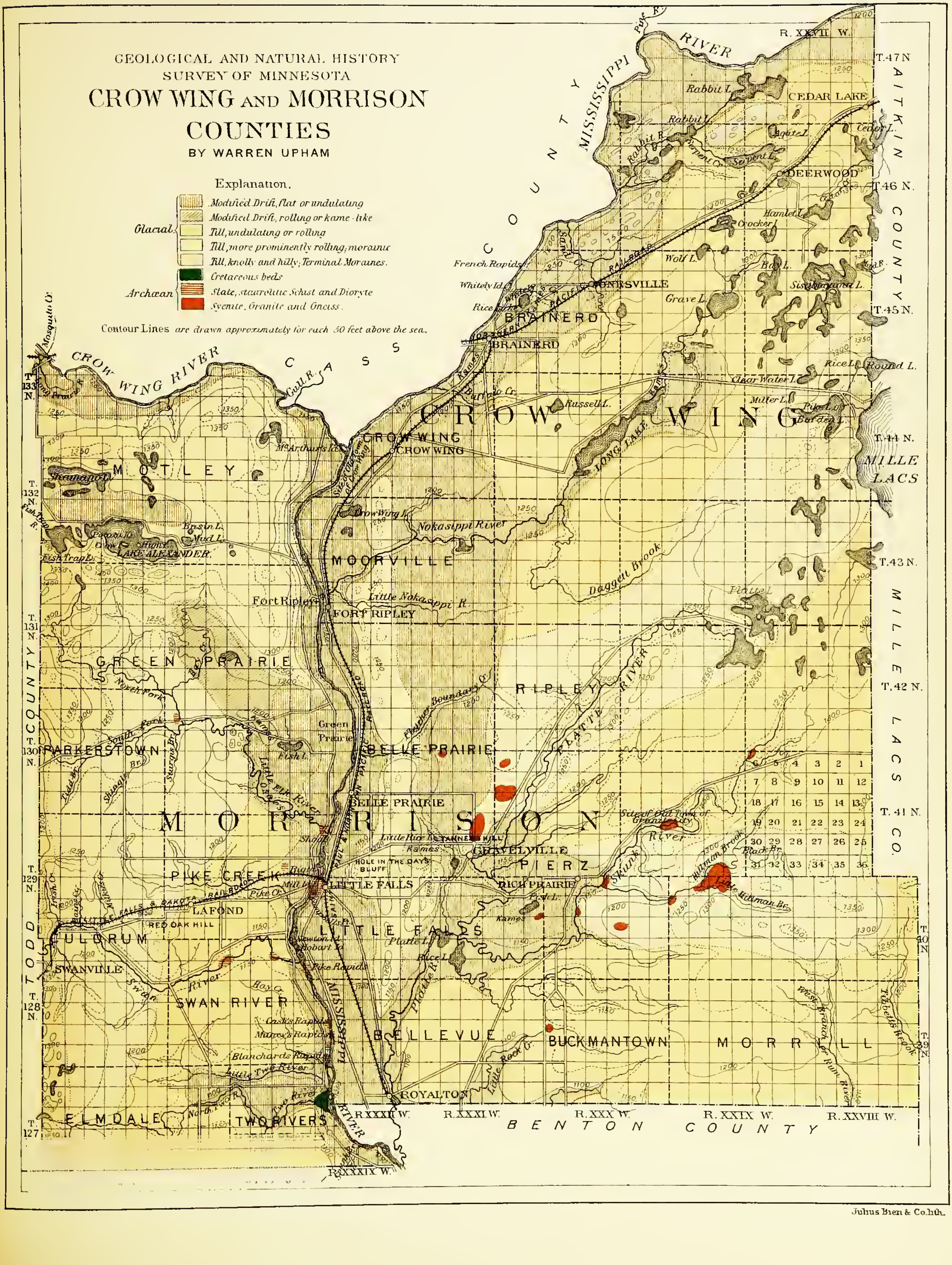
BY WARREN UPHAM.

Situation and area. Crow Wing and Morrison counties (plate 53) lie in the centre of Minnesota. Its exact geographical centre is very close to Fort Ripley and the mouth of the Nokasippi river, their parallel and meridian dividing the state into four parts that are nearly equal in area. Little Falls, the county seat and largest town of Morrison county, is about 90 miles northwest from Minneapolis and Saint Paul; and Brainerd, the county seat and largest town of Crow Wing county, is 27 miles north of Little Falls. Other important villages are Deerwood in Crow Wing county, and Belle Prairie, Royalton, Gravelville, Rich Prairie or Pierz, Swanville and North Prairie in Morrison county. Crow Wing, on the east side of the Mississippi river opposite the mouth of the Crow Wing river, was once a large town, being prominent in the early history of Minnesota as an Indian trading-post. Granite City, about five miles northeast from Rich Prairie in Morrison county, was a considerable village before the Indian outbreak in 1862, when it was abandoned.

Crow Wing county has an approximately triangular form, being 29½ miles long from north to south, and 28 miles wide in its southern tier of townships. Its area is 574.74 square miles, or 367,838.13 acres, of which 42,494.63 acres are covered by water.

Morrison county is about 40 miles long from east to west, and its greatest width, on its western boundary is 39½ miles, but east of the Mississippi river its width is only 23 miles. The area of Morrison county is 1,154.82 square miles, or 739,088.97 acres, of which 8,171.77 acres are covered by water.

PLATE 53



Julius Bien & Co. lith.

SURFACE FEATURES.

Natural drainage. The Mississippi river is the north and west boundary of Crow Wing county; and it flows southward across Morrison county, dividing it into nearly equal parts. Its chief tributaries from the east in these counties are Rabbit river, Sand creek, Nokasippi river, Fletcher creek, and Platte river. The largest of these is the Platte river, which has its source in the Platte lakes on the line between Crow Wing and Morrison counties, thence flowing southwesterly thirty miles and uniting with the Mississippi in the northwest corner of Benton county. Skunk river is an important tributary to the Platte from the east. The affluents to the Mississippi river from the west are the Crow Wing river, which forms the northern boundary of that part of Morrison county, the Little Elk river, Pike creek, Swan river, Little Two rivers, the "main Two rivers," and Spunk brook. Lake Alexander and Fish Trap lake in northwestern Morrison county are the sources of the Fish Trap brook, which flows northwesterly into Todd county, being tributary to the Long Prairie river and by that to the Crow Wing. The east border of these counties from Mille Lacs southward belongs to the basin of Rum river, which is tributary to the Mississippi at Anoka.

Lakes. Mille Lacs, which touches the east line of Crow Wing county, is one of the largest lakes wholly included within the limits of Minnesota. The other principal lakes of Crow Wing county are Round lake and Pike or Borden lake, tributary to Mille Lacs; Sisabagama lake and others, forming the head of Mud river, which joins the Mississippi at Aitkin; Serpent lake at Deerwood, the head of Rabbit river; Grave and Long lakes, through which the Nokasippi river flows; and the Platte lakes on the south line of this county.

Excepting the Platte lakes just mentioned and others in their vicinity, eastern Morrison county has few lakes, the most noteworthy being the Rice lakes, the southern Platte lake and Fish lake, lying between Little Falls and Rich Prairie. In western Morrison county only a few little lakelets occur south of Lake Alexander, Fish Trap and Shamano lakes, which, with several others of small size, make up an interesting group in the northwest part of the county, beautiful for their hilly shores, numerous points, bays and islands, and abounding in fish and water-fowl, while deer and other game live in the surrounding forest. The same attractions to the sportsman are also supplied by the lake region of the upper Platte and Nokasippi rivers, about Mille Lacs, and around Deerwood.

Topography. These counties present much variety in their topographic features. A roughly hilly belt of morainic drift, chiefly till, with scanty kame-like deposits of gravel and sand, borders the west side of Morrison county, lying mainly in Todd county but reaching in some places a mile or two across the county line into Elmdale, Culdrum and the south half of Parkerstown. North from the south fork of Little Elk river it reaches two or three miles into Morrison county in the northwest part of Parkerstown and the township next north. It then turns eastward and occupies a width of two miles south of Fish Trap lake and lake Alexander, above which these morainic hills rise 100 to 150 feet. Similar drift hills, but of less hight, border the northwest side of Fish Trap lake and the north side of the east half of lake Alexander, Next to the north a width of one to two miles between these lakes and Shamano lake, and extending from the county line about seven miles to the east, is undulating and in part nearly level modified drift, being a sandy and gravelly area of "brush prairie," while the more clayey moraines both south and north of it are heavily timbered. North of Shamano lake, morainic hills of till occupy a width of two or three miles, separated from the Crow Wing river by a mile or more of modified drift which is gravel and sand, partly level or moderately undulating and partly in low hillocks and ridges. Farther eastward a broad morainic area extends from the Crow Wing river fifteen miles south, having a width of six to ten miles from lake Alexander and Shamano lake east to the Mississippi river. Its highest portions rise about 100 feet above lake Alexander, or 200 to 250 feet above the Crow Wing and Mississippi rivers. Adjoining the mouth of the Crow Wing, and at Fort Ripley and for the next three miles southward, low and nearly level tracts of gravel and sand belonging to the modified drift, averaging about a mile in width, lie between these morainic hills and the Mississippi river.

On the north side of the Little Elk river, between it and the morainic area, a large tract of modified drift extends a dozen miles northwest from the Mississippi, narrowing from six miles in width at the east to about two miles in T. 131, R. 30. Its northwest extremity is two or three miles south from the east end of lake Alexander. Green prairie, adjoining the Mississippi, and most of this tract west to Fish lake, are flat or only slightly undulating. From the west end of Fish lake, kames or knolls, small plateaus and short ridges of gravel and sand, having cobbles up to one foot in diameter but no larger boulders, rising 30 to 50 feet above the smoothly undulating gravel and sand on each side, extend three miles west-northwest, with an average width of about a mile. Two to three miles south of Fish lake similar kames, and prolonged ridges of such modified drift, called osars, run one or two miles from northwest to southwest on each side of the Little Elk river and parallel with it, in section 36, T. 130, R. 30, extending into portions of adjoining sections. These ridges are popularly denominated "horse-backs" and "hog-backs." Their hight is 40 to 60 feet above the adjoining country or 50 to 75 feet above the Little Elk river.

Southward from the morainic area and this tract of modified drift, most of the southwest part of Morrison county is moderately undulating or rolling till, rising in smooth swells 20 to 40 feet above the water-courses. In southeastern Elmdale, south of the north branch of Two rivers the surface for several miles is very level till, and this continues into the edge of Stearns county. Between the main Two rivers and Little Two rivers a belt of level gravel and sand of the modified drift extends from the northeast part of Elmdale east to the Mississippi river. A similar plain, mostly from a half mile to one mile wide, borders the Mississippi through Little Falls, Swan River and Two Rivers, with a hight 25 to 50 feet above the river, being highest (as compared with the river) toward the south. Its narrowest place is half-way between Swan river and Pike creek, and its greatest width is two miles in the north part of Little Falls west from the mouth of Little Elk river.

East of the Mississippi a morainic belt one to two or three miles wide extends from north to south through Moorville, Belle Prairie and Little Falls nearly parallel with the Mississippi river, from which it is separated by a plain of modified drift one to three miles wide and 25 to 50 feet above the river. Along the northern two-thirds of this morainic belt, its elevations are only 40 to 75 feet above the valley-plain, thus averaging about 100 feet above the Mississippi, but in the south edge of Belle Prairie and in Little Falls its hight is from 100 to 200 feet. Where it is crossed by the road from Little Falls to Rich Prairie, it attains nearly its greatest hight, and its material is almost wholly till or boulder-clay. On another road that crosses this moraine one to one and a half miles farther north, where its hight is 75 to 100 feet, the material forming the surface is sand and coarse gravel, with cobbles up to about one foot in diameter but no large boulders. The same modified drift forms Hole-in-the-Day's bluff, a notable conical hill, 40 feet above the average hight of the range and about 150 feet above the Mississippi, situated in the south edge of Belle Prairie, one and a half miles northeast from Little Falls. The many knolls and short ridges making up the moraine in that vicinity are all such modified drift, but till probably forms the core of the range. Three or four miles farther north, this moraine east of Belle Prairie village is mostly till; and this, with considerable kame-like gravel and sand, forms its extension northward in this township and Moorville.

Next east of this moraine, modified drift covers a width of three to six miles, excepting in the southeast corner of Belle Prairie, where it is narrowed to one mile. In the east part of Little Falls and southwestern Pierz, this tract of gravel and sand widens to seven or eight miles from east to west; and thence being again contracted to a narrow belt, it continues southwest through Bellevue to the Mississippi. On the north this tract also reaches to the Mississippi river in Crow Wing, Brainerd and townships farther north, having there a width of two to four miles east of the river. Its contour is for the most part flat or only slightly undulating, but in some portions it is knolly, ridged and even hilly. About Rice lake on Whitely creek, two miles northeast from Brainerd, it consists of kames, or short, irregular hills and ridges of coarse gravel and sand, varying from 50 to 125 feet in hight. At Brainerd it is a flat plain 50 to 60 feet above the Mississippi river. In the next three miles southwestward, its surface is again in kame-like hillocks and ridges, 20 to 40 feet above the enclosed hollows; but through the six miles thence to the old town-site of Crow Wing it is nearly level. In Morrison county kame-like portions were observed west of Little Rice lake in the south part of Belle Prairie, where the surface is rather massively rolling; and on the southwest side of Fish lake, where knolls and short ridges 20 to 40 feet high cover a small area.

Farther east both these counties are mainly till, but limited tracts of modified drift are found here and there. One is at the northeast end of Long lake, where kames 50 to 75 feet high occupy a width of nearly a mile, lying mostly on the west side of the Nokasippi river and the head of the lake, from which a nearly level tract of gravel and sand extends three miles eastward. Another deposit of gravel and sand, flat or slightly undulating, extends from Borden lake east to Mille Lacs and Round lake, having a length of three miles adjoining Mille Lacs, partly in Aitkin county, with a width of one mile and a hight 10 to 30 feet above these lakes. The surface of the till from Deerwood south to Sisabagama lake, and thence southwest to Daggett brook and the belt of modified drift in Crow Wing and Moorville, is moderately undulating or rolling, with the crests of its swells 10 to 30 feet above the depressions. A more prominently rolling and hilly morainic belt extends from the highest part of the moraine in Little Falls northeastwardly by Tanner's hill, 100 feet high, a mile northwest of Gravelville, along the upper Platte river and between the Platte lakes and Daggett brook, to the northwest side of Mille Lacs. Its hills near the Platte river in T. 42, R. 30, are 50 to 100 feet high. In T. 44, R. 28, a hill in this belt about 150 feet high is crossed by the line between sections 21 and 22, and another about 100 feet high lies in section 24, close to Mille Lacs, being the most prominent elevation seen on this lake in the entire circuit of its shore. About Pike or Borden lake and north of Round lake the morainic swells and hills are 40 to 75 feet high. South of this moraine the sheet of till regains its more smoothly undulating and rolling surface, but includes some morainic accumulations on the Hillman brook and its tributaries and near the sources of the West branch of Rum river.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, Saint Paul.

a. *Duluth line.*

	Miles from Duluth	Feet above the sea.
Summit, cutting 8 feet; grade	97.5	1298
Deerwood	98.2	1274
Swamp, grade	100.0	1268
Summit, cutting 18 feet; grade	103.6	1290
Y of Saint Paul & Minneapolis line	114.9	1207
Brainerd	115.0	1209
Mississippi river, bed, 1144; extreme low water, 1150; extreme high water, 1167; grade on bridge	115.5	1211

b. *Saint Paul & Minneapolis line.*

	Miles from Saint Paul.	Feet above the sea.
Royalton	96	1081
Little Falls	106	1115
Belle Prairie	111	1131
Summit	118.5	1173
Fort Ripley	120	1159
Nokasippi river, water	120	1139
Crow Wing	127	1187
Buffalo creek, water, 1173; grade	133.5	1204
Summit	134.5	1202
Buckhorn creek, water, 1165; grade	136	1190
Junction at Brainerd	137	1207

c. *Little Falls & Dakota railroad (leased to Northern Pacific railroad.)*

	Miles from Little Falls.	Feet above the sea.
Little Falls	0.	1115
Mississippi river, bed, 1076; grade	0.5	1110
Pike creek, bed, 1104; grade	3.8	1116
Summit, cutting 4 feet; grade	6.8	1196
La Fond	7.2	1184
Summit, cutting 2 feet; grade	9.2	1211
Summit, cutting 1 foot; grade	10.5	1212
Milkie's creek, bed, 1172; grade	11.0	1183
Bain's run, bed, 1155; grade	13.1	1164

	Miles from Litte Falls.	Feet above the sea.
Irish creek, bed, 1152; grade	13.7	1159
Swan river, bed, 1149; grade	14.3	1162
Swanville	16.0	1173
Summit, cutting 6 feet; grade	17.0	1192

The following elevations of the Mississippi river at its ordinary low-water stage have been determined by the United States engineer corps under the direction of Capt. C. J. Allen. (These figures require a subtraction of three feet to accord with the railroad elevations preceding. Both series are referred to sea-level by accepting the elevation of lake Superior determined by the United States lake survey, 602 feet above mean tide).

Mississippi river.

	Feet above the sea.
At Aitkin	1193
At the east line of Crow Wing county, about	1188
Mouth of Pine river	1180
Head of Big Eddy rapids	1173
Foot of Big Eddy rapids	1171
At Island rapids (fall about one foot in a sixth of a mile)	1167
At Brainerd	1155
Mouth of Crow Wing river	1148
Mouth of Nokasippi river	1142
Head of Conrad's shoals	1109
Foot of Conrad's shoals	1107
Head of Little Elk rapids	1105
Ferry at head of rapids, Little Falls	1093
Foot of rapids, Little Falls, opposite south part of Mill island	1086
Head of Pike rapids	1070
Foot of Pike rapids	1067
At upper end of McDougall's island	1036
At south line of Bellevue	1034
Mouth of Platte river, at south line of Two Rivers	1029

The descent of the Mississippi river within the limits of these counties is thus 159 feet. The Crow Wing river at Motley is 1,206 feet above the sea, descending nearly 60 feet thence to its mouth. Mille Lacs, as determined by the United States engineers, is 1,251 feet above the sea; and the Platte lakes at the head of Platte river, and Sisabagama and Grave lakes, have nearly the same hight. Long lake on the Nokasippi river is estimated to be 1,225 feet, and lake Alexander 1,275 feet above the sea.

Morainic hills near the west shore of Mille Lacs, in T. 44, R. 28, 1,350 to 1,400 feet, and the Mississippi river at the mouth of the Nokasippi, 1,142 feet above the sea, are the extremes of elevation in Crow Wing county. The mean elevation of this county is approximately 1,260 feet.

The highest land in Morrison county consists of morainic hills in the neighborhood of lake Alexander, the tops of which are about 1,400 feet above sea-level; and its lowest land is the shore of the Mississippi river in Two

Rivers township, 1,029 feet. Estimates of the average hights of the townships are as follows: T. 42, R. 28, 1,275 feet; T. 41, R. 28, 1,300; T. 40, R. 28, 1,275; Morrill, 1,225; T. 42, R. 29, 1,260; T. 41, R. 29, 1,260; T. 40, R. 29, 1,275; Ripley, 1,260; Pierz, 1,220; Buckmantown, 1,180; Belle Prairie, 1,180; Little Falls, 1,160; Bellevue, 1,100; Motley, 1,275; Green Prairie, 1,230; Pike Creek, 1,170; Swan River, 1,140; Two Rivers, 1,100; Parkerstown, 1,260; Cudrum, 1,240; and Elmdale, 1,200. The mean elevation of Morrison county, derived from these figures, is approximately 1,220 feet.

Soil and timber. The boulder-clay or till is good farming land, except very limited portions of the morainic belts which are too hilly and stony for cultivation, and such areas are valuable for pasturage. The soils of gravel and sand belonging to the modified drift have less fertility and are more quickly exhausted by cropping; but from Motley to Crow Wing and thence southward through Morrison county they are fairly productive, and have been in large part brought under cultivation because they were prairie or only covered by brush and small trees, so that the land was easily cleared and prepared for the plow. About Brainerd and northeastward the gravel and sand deposits are less fertile and are but little cultivated; this difference being chiefly due to the lack of limestone which is a considerable ingredient in the modified drift farther west and south.

Heavy timber covers the areas of till and some portions of the modified drift. On the latter jack pines, red or "Norway" pines, black and bur oaks, and the poplar or aspen, are the characteristic species of trees. The site of Brainerd was a thick forest of jack pines, growing with very straight trunks forty to sixty feet high and eight to twelve inches in diameter. Much jack pine also grows on a belt next east of the moraine in Crow Wing, Moorville, Belle Prairie and Little Falls; and much red pine is found on the tract of modified drift in Green Prairie north of the Little Elk river. More numerous species of trees flourish on the till soils, including the white pine, black spruce, balsam fir, white, bur and black oaks, ironwood, white, red and rock elms, hackberry, basswood, sugar and soft maple, box-elder, black and green ash, canoe and yellow birch, poplars, butternut, bitter hickory, wild plum, red and black cherries, and Juneberry. Among the shrubs are the hazel-nut, prickly ash, choke-cherry, red and black raspberries, high blackberry, wild rose, thorn, prickly and smooth gooseberries, black currant, wolfberry, staghorn and smooth sumach (the former extending west to lake Alexander), frost grape, Virginia creeper, climbing bitter-sweet, New Jersey tea or red-root (plentiful on sandy land), species of cornel, honeysuckle and arrow-wood, the high bush cranberry, alder, and willows. There is abundance of strawberries, running blackberries, low blueberries, aromatic wintergreen or checkerberry and bearberry (in sandy pine woods), dwarf cornel or bunch-berry, sand cherries on prairies, and cranberries and creeping snowberry in bogs. Tamarack is plentiful in swamps. Red cedar occurs rarely on bluffy shores of rivers and lakes. Arbor-vitæ grows in a swamp near the west side of Borden lake, this being apparently its southern limit, though it also occurs south of Mille Lacs.

The general southwestern limit of the pines, spruce and fir, crosses Buckmantown, Bellevue and the south part of Swan River, thence continuing northwestward through Culdrum into Todd county. Much white pine has been cut, and much remains, in Parkerstown and thence northward in Green Prairie and Motley, about the head of the West branch of Rum river, on Hillman brook, and on the upper portions of Skunk, Platte and Nokasippi rivers.

Prairies of grass with scarcely any shrubby plants occupied a considerable part of the modified drift plain bordering the east side of the Mississippi river southward through Belle Prairie and part of Little Falls; also a tract of two or three square miles in the southwest part of Bellevue; and another about three miles long from north to south and a mile wide in Crow Wing. Green prairie, also three miles long from north to south and a mile wide, North prairie in Two Rivers, and Rich prairie, which is three to four miles wide and reaches eleven or twelve miles from the middle of Pierz south through the west part of Buckmantown and the east edge of Bellevue, continuing onward into Benton county, are mostly "brush prairie," having much hazel and oak brush, prairie willow, red-root and sand cherry, and occasionally scattering trees and groves of small black and bur oaks, poplars, and jack pine.

GEOLOGICAL STRUCTURE.

Archæan rocks.

No outcrops of the bed-rocks are known in Crow Wing county, but they occur at many places in Morrison county. Their prevailing types east of the Mississippi are granite, syenite, and gneiss. Along this river and farther west they are slate, staurolite-bearing mica schist, and dioryte. The former belong to a group which has its characteristic development in the syenites of Benton and Stearns counties, and in the granites and gneisses of the upper Minnesotā valley. Though the geographical continuation of the second group of slate and associated rocks cannot be traced because of overlying drift, their lithological character shows them to be probably connected and of the same age with the slates of the lower part of the St. Louis river and its vicinity. The hydromica schists found in Carlton county near Moose Lake station may also belong to this second group.

It seems probable that the slate, staurolitic schist and dioryte of Morrison county, and of northern Todd county at and east from the mouth of Fish Trap brook, form a synclinal axis or basin bounded both east and west by formations of granite, syenite and gneiss. In describing the ledges observed in Morrison county, these groups are treated of separately, the eastern, mostly granitic and gneissic rocks, which are believed to be the older, being first considered.

Buckmantown. The only rock-outcrop in this township, so far as learned of, is on land of A. B. Skinner, in the S. W. ¼ of the N. W. ¼ of section 18, a short distance east of the road which runs on the west line of the township, and north of a small creek. It is a coarse-grained, reddish syenite, nearly like that which occurs at many places in Sauk Rapids and Watab, Benton county. Several exposures of the rock are seen upon a space of about one acre, the largest being about four rods long from north to south, and rising three or four feet above the gravel surface. Many blocks, four to fifteen feet in diameter, are scattered near.

Rich Prairie and vicinity. Proceeding northward toward the village of Rich Prairie, in Pierz township, the next exposure of rock is found about one and a fourth miles south of this village. It is at the east side of Skunk river, in the S. W. ¼ of section 17, on land of John Stumpf. Its area is equal to about forty feet square, and its hight is ten feet above the river. This rock is a gray granite, containing considerable black mica.

One and a half miles west from the last, and about a third of a mile south of Fish lake, upon the S. E. ¼ of section 13, T. 40, R. 31, is an outcrop of rock extending about fifteen rods from east to west and twelve rods from north to south, rising four or five feet above the general surface. Its eastern part is owned by Nicholas Meyer, and its western part by Anton Rauch. This is a fine-grained, light gray granite, very uniform in texture, with no veins or masses of other rock visible. It is divided by joints into beds one to two feet thick, dipping about 20° S., but it is not cut by vertical joints. It has been only slightly quarried, by Mr. Meyer for cellar walls. This stone has a pleasing color for building and monumental work, and a good degree of strength and durability. It is readily quarried in any dimensions that are ordinarily called for, and is easily cut or hammered. The ledge is valuable for quarrying, and a large excavation may be made without trouble from water, as the surrounding land is the porous sand and gravel of the modified drift; which also affords a nearly level and dry road for hauling the stone away.

About three miles southeast from Rich Prairie, exposures of the bed-rock, probably granite, are reported to cover three or four acres, on land of Mathias Neuman, in the S. ½ of the N. E. ¼ of section 22. It has been slightly quarried.

One mile east of Rich Prairie or Pierz, the east bank of Skunk river between forty and eighty rods north of the mouth of Hillman brook has frequent outcrops of gneiss, rising one to three feet above the general surface and ten to twenty feet above the stream, next to which they occupy a belt about six rods wide. This gneiss contains black mica and flesh-colored feldspar, the latter being sometimes gathered in layers or veins one to three inches wide. All these outcrops are more or less laminated, this structure being nearly vertical. They are all somewhat contorted and jointed. The strike is N. E. or N. 50° E., bearing in the direction of "Granite City," four miles distant, where similar gneiss has extensive exposures.

Along Hillman brook. In ascending this brook, my first observation of rock in place was at its lowest "roll dam," situated about three and a half miles above its mouth, in the north part of the N. W. ¼ of section 18, T. 40, R. 29. This outcrop is at the north end of the dam, and occupies an area about four rods long from north to south, by twenty to forty feet wide. Its southeastern two-thirds are gneiss, nearly like that described, rather obscurely and contortedly foliated but indicating a N. E. to S. W. strike. This gneiss has much black mica and flesh-colored feldspar, and it is traversed by veins of this feldspar from an eighth of an inch to six inches wide. One of these veins, varying from three to six inches in width, nearly vertical, is visible for an extent of twenty feet in a straight east-to-west course. The joints of the gneiss are from two to ten feet apart.

The northwestern third of this ledge, extending within sight twenty feet from north to south and ten feet wide, is a fine-grained granite, containing much feldspar, which is partly gray and partly flesh-colored. This portion of the ledge is probably part of a dike or mass of erupted rock; it is rhomboidally divided by intersecting systems of joints, which are from two to twelve inches apart.

Ledges occur frequently in the vicinity of the second and third "roll dams," situated respectively about forty rods below and twenty rods above the mouth of the Little Hillman brook, tributary to the main stream from the south. About a mile above the mouth of the Little Hillman brook and a short distance, perhaps a quarter of a mile, above its dam, this stream is reported to flow some twenty rods in a gorge with walls of rock at each side, five to twenty feet high. Also, frequent outcrops of rock are found between these streams from their junction east and northeast to the "big dam" of Hillman brook.

This "big dam" is on the S. E. ¼ of section 35, T. 41, R. 29, about sixty rods west of its east line, and twenty rods south of its north line. Rock-outcrops of considerable extent occur at several places upon each side of the Hillman brook for a fourth or a third of a mile below and along an equal distance above the "big dam." These are gneiss and granite with the same characters as at "Granite City" and in the vicinity of Rich Prairie. Farther east the region drained by this brook and its tributaries has no known exposures of rock.

At the south end of this dam, about 400 feet south of the sluice-ways, the gneiss is typical, including much black mica. Its coarse foliation is nearly vertical, with strike varying from N. 25° E. to N. 40° E. At the north end of the dam, 100 feet north of its sluices, the rock is a fine-grained gray granite, with black mica, nearly like that on land of Meyer and Rauch, south of Fish lake and a few miles southwest of Rich Prairie. This granite is here exposed upon an area which extends at least twenty rods east and ten rods west from the dam, and is from three to six rods wide. Mostly it is divided into rhomboidal masses from a few inches to four or five feet in dimension by joints, and no portion seen was sufficiently free from joints to yield large quarried blocks; yet it is quite likely that good quarry-stone would be obtained by excavating a few feet in depth. The texture and rift are nearly the same as south of Fish lake, to which this formation is probably continuous; the rock is equally compact and uniform in quality; and the color, though on the surface here weathered to a dull brownish tint, would probably be the same handsome gray as at Fish lake in deep quarrying.

"*Granite City.*" In the west part of section 21, T. 41, R. 29, on the northwest side of Skunk river, is the site where a steam saw-mill and a considerable town existed during several years next preceding the Indian outbreak of 1862. Its buildings remained empty from that time and were gradually removed or burned, the last continuing until 1873. The nearest farming immigrants are found about a half mile down the river, and from them northeastward the region drained by the upper part of the Skunk river and extending to Mille Lacs is an unbroken forest.

The rock outcropping at "Granite City," from which the name arose, is coarse gray gneiss, containing much black mica. Its strike is from northeast to southwest, and its dip is vertical or within a few degrees of it, being in some places 85° or 80° to the northwest, and elsewhere the same to the southeast. This rock forms numerous bare hillocks and ridges, ten to thirty feet above the Skunk river, for a fourth of a mile along its northwest side, and occurring in less amount on its southeast side. It is also seen on the southeast side in an exposure of a few acres, rising ten to twenty feet above the river at a fourth of a mile farther east. All these outcrops, so far as seen, are gneiss, everywhere more or less contorted, often quite twisted and bent in lamination for short spaces, but having throughout a prevailing N. E. to S. W. strike and nearly vertical dip. The Skunk river is here ten to twenty feet wide, and flows in a meandering course among these ledges.

About six miles above "Granite City," on the northwest side of Skunk river, a little beyond where this stream is crossed by the road used for carrying the supplies distributed yearly to the Mille Lacs Indians, rock exposures are reported to cover as large an area as at "Granite City," but to have less hight above the adjoining surface of the drift. This is in or near the northwest corner of T. 41, R. 28.

Near the Platte river. Numerous outcrops of rocks occur within one to two miles west of the Platte river through the six miles next north of Gravelville, which is an enterprising new village, with mills, situated on this river in the N. E. ¼ of the N. E. ¼ of section 35, T. 41, R. 31. The first of these ledges is one to two miles north of Gravelville, in the N. E. ¼ of section 26, the east edge of section 23, and the west part of section 24, T. 41, R. 31. The longest extent of this tract is from northeast to southwest, reaching a mile and probably including sixty to eighty acres of rock. In the N. E. ¼ of section 26 it is granite, sometimes pink and sometimes gray, rising eight or ten feet above the general surface, which is nearly level. In the W. ½ of the N. W. ¼ of section 24, these ledges rise ten to twenty feet above the adjoining swamps. The rock here is a dark gray gneiss, mostly obscure in its lamination. The strike, at least in part, is S. 70° W., but generally, because of the contorted and indistinct lamination, it is not clearly exhibited.

In the north part of section 18, on land of John F. Whitney, and in the adjoining south part of section 7, T. 41, R. 30, one and a half miles northeast from the last locality, are extensive exposures of the same dark gray gneiss last described. This contains considerable black mica. It is for the main part obscurely laminated, and, though nowhere a true granite, it is rarely so definite in its foliation as to show strike and dip. In some portions the strike is seen to be from north to south; and the dip appears to be nearly vertical. Beginning near Mr. Whitney's house, close to the centre of section 18, frequent outcrops of this rock, rising one to five feet above the general surface, continue north to the north side of this section and into section 7. This section line crosses the most extensive of these tracts of rock, which covers some thirty acres, and here rises 25 or 30 feet above the adjoining swampy tracts. This gneiss has a nearly uniform character throughout the half mile here seen. Another outcrop of rock, probably the same, is reported one and a half miles farther north, near the centre of section 6, covering about ten acres, and rising five to ten feet above the general surface. Three miles west from this a small ledge, covering five or six rods square, and one to three feet high, was found by surveyors near the middle of the north side of section 3, T. 41, R. 31, five miles east-northeast from Belle Prairie. Other ledges, which have not yet been observed, will probably be found in this district when its woods are cleared away. Thence northward to Brainerd and northeast to Mille Lacs, and beyond, no exposures of the bed-rock are known.

Slates, staurolite-bearing mica schist, and dioryte. The rocks which remain to be described in Morrison county, found along the Mississippi river and west of it, belong, as already stated, to a group lithologically different from the foregoing, and probably newer in age. The first exposure is on the Little Elk river near its mouth, about two and a half miles north of Little Falls. The most extensive outcrop here, about six rods square and ten feet in hight, is on the northeast side of the Little Elk river, opposite Henry S. Hill's mill, about thirty rods above the mouth of this stream. This rock is dark, nearly black slate (argillyte), like that of Little Falls. It continues upon this northeast shore about ten rods down stream, southeastward, and for a few rods northwest above the dam; and is also visible in low exposures at the bridge, twenty rods above the mill. Opposite the mill the course of the cleavage is N. 40° E. (referred, as are all the bearings stated in these chapters, to the true meridian), and its dip is nearly vertical, varying to 80° S. E This slate contains occasional veins of white quartz, from a quarter of an inch to two or three inches in width and one to twenty feet or more in length. These coincide closely with the cleavage in their strike and verticality. These slates throughout are rather soft and easily broken; and they are much divided, usually into rhomboidal masses from two or three inches to one foot in dimension, by joints. In one system of these joints, dipping about 60° S. E., they are mostly six to twelve inches apart in parallel planes. Other joints, dipping 20° to 45° to the north-northwest and from that to north, and a system dipping 15° W., are about half as numerous as those first mentioned. Another system of joints, cutting these, is vertical, or between vertical and dips of 60° to each side, with their strike between west-northwest and north-northwest. No macroscopic staurolite, garnet, nor pyrite crystals were noticed here, but distinct laminæ, made by aggregation of minute crystals of staurolite or mica, not fissile and extending transversely across the cleavage, are found in much of this rock, nearly as at Little Falls. These probably mark the original lines of stratification, but unfortunately their dip and strike here were not noted. The Mississippi river between this locality and Little Falls has numerous alluvial islands.

At the ferry, a half-mile above Little Falls, this slate has low outcrops two to six or rarely eight feet above the river. On the west side these are seen at several places for twenty rods below the ferry. On the east side they are best exhibited at the ferry-landing and for eight or ten rods farther north. The cleavage here bears N. 35° to 40° E., and is nearly vertical. Some four rods north of the landing a very compact layer occurs, ten feet thick, showing scarcely any slaty cleavage. About two rods farther north a quartz vein a foot wide was noted, conformable with the cleavage.

At the rapids, or Little Falls of the Mississippi, beside the town of this name, this dark slate, varying from mica schist to argillyte, has extensive outcrops in each shore, and forms the north end of Mill island, on the west side of which it makes a perpendicular cliff twenty feet high. The principal rapid extends a fifth of a mile from about 600 feet above this island to 500 feet below its north end, the descent being five feet. Here the slate has mainly a firm and strong texture, having been only slightly decomposed or softened by weathering; but it is too variable in its cleavage, and is too frequently contorted and intersected by veins and joints, to promise well for quarrying for roofing-slate. It has been slightly quarried on the east shore, nearly opposite the north end of Mill island, for use in foundations, but no massive blocks nor any of regular form are obtainable. Its cleavage is usually quite perfect, into sheets a fourth or an eighth of an inch in thickness; it is nearly vertical, not varying from this more than five degrees to either side, so far as seen in my examination; and its strike is N. 25° to 35° E. A lamination transverse to the cleavage, and supposed to indicate the original planes of sedimentation, but not showing any tendency to split, was found well exhibited in a section twenty feet long and five feet high, at the outmost point beside the river on the east shore. The laminæ or layers referred to are from a twentieth to an eighth of an inch thick, and differ from the remainder of the macroscopically homogeneous slate in containing many minute crystals of staurolite and perhaps mica. These layers, which are very distinct, show many small undulations; but in respect to their entire extent, run nearly in a straight line. Their dip is about 15° N. W. White quartz veins occur somewhat frequently in this slate, varying from an eighth of an inch to three inches in width, and extending from ten to fifty or seventy-five feet. Their strike and dip are conformable with the slaty cleavage. The thickest of these veins, situated in the channel of the river, is said to be one foot wide. In the east part of Little Falls this slate is encountered at the depth of about ten feet in digging wells; but it is not found thus in the west part, between this and its exposure at the river.

In some small portions of these outcrops the slaty cleavage is absent or scarcely noticeable, and the rock, massive, compact and hard, with sharp jointage angles, is apparently a dark quartzyte. Professor Winchell adds:* "Besides these variations there are nearly continuous layers of more or less lenticular and concretionary lumps or nodules, sometimes six or eight inches thick, of a rock very firm and dark-colored, but which on weathering becomes superficially lighter-colored, and shows needles and spangles of dark-green amphibole. The matrix in which those crystals lie is not well characterized, but is quartzitic and perhaps also feldspathic, so that on a fresh fracture the amphibole crystals are hardly observable. They appear on the weathering of the rock. . . . . A system of joints gives the rock, viewed across the river, the appearance of being conspicuously stratified, with a dip up the river of about 45 deg. from the horizon. The slatiness, which is nearly perpendicular, is somewhat injured, at least superficially, by the frequency of joints, of which there are at least two systems intersecting each other at a small angle, thus cutting the slates into rhomboidal masses, as they weather to pieces. . . . . Opposite the village of Little Falls a trap dyke of basic doleryte, apparently about 10 feet wide, appears in the slate, going diagonally across the slate; and on the south side of the dyke, in the lee of its protection against the current of the river, as well as against, possibly, the ice of the ice-period, the slate (or schist) is decomposed to the depth of four or five feet at least, making a greenish-blue clay, or incipient kaolin."

At Campbell's point, on the east shore of the Mississippi, about a half mile south of the middle of Little Falls village, and about a fifth of a mile south from the south end of Mill island, rock is exposed along a distance of five or six rods, rising eight or ten feet above the river. In describing this rock and its probable origin, professor Winchell states that it "consists, in general, of a hard, dark-colored dioryte, containing mainly amphibole in coarse crystals, and a little feldspar (labradorite?). The outward characters of this rock are the same as the concretionary lumps that exist in the slate already described. It is here simply in larger area and bulk. It is parted by joints that cause it to fall to pieces in slabs and cuboidal masses. This *may be* here in the form of a dyke, but its relation to the slate cannot be seen. The point which is formed by it is considerably higher than the bottomland on either side, but falls away somewhat on receding from the river, the rock itself becoming lost to view in the swampy bottoms, or involved with the drift of the

* *Sixth annual report*, p. 50.

river-bluffs. On long-weathered surfaces, under the action of the water, there is a ridged and furrowed form that shows the same direction and trend as the slatiness of the slate, i. e. N. 18 deg. E. [magnetic]. The ridges are about $\frac{1}{4}$ inch apart, and about $\frac{1}{8}$ or $\frac{1}{4}$ inch high, separated by intervening furrows. This surface configuration is apparently due to the alternate arrangement of the mineral contents, and perhaps has its origin in a metamorphosed condition of the slate itself, or of the sedimentary rocks from which they both may have been derived. Thus this could not be of the nature of an igneous dyke, but a metamorphic variation due to the complex nature of the original sediments. This view is strengthened by the occurrence of a similar dioryte rock, in concretionary masses, in the slate itself, running in more or less regular layers or lines. This alternation of mineral contents does not pervade the whole of the rock exposed on 'the point;' but it is a conspicuous feature in some places. The ridges are composed of the lighter-colored minerals, and the furrows of the amphibole."

At Pike rapids, which are three and a half miles south of Little Falls and about a quarter of a mile south of the mouth of Swan river, numerous low outcrops of schist occur in the banks and channel of the Mississippi along a distance of about an eighth of a mile, from the head to the foot of these rapids, which descend about three feet. The rock here is a mica schist, containing many large crystals of staurolite and often small garnets. No veins or masses of quartz were noticed. On the west shore, which is only six to ten feet high, its exposures are numerous, but rise only one to five feet above the water. It rises in the channel of the river above its bed of boulders and sometimes above the water at frequent intervals across its whole width, the most conspicuous of these ledges being an island eight or ten feet high near the east side of the river. Small and low outcrops are also seen in the east shore, which is a steep bank of glacial drift, or till capped with gravel, about 40 feet high. This rock has a laminated structure, which corresponds in strike with the cleavage of the slate at Little Falls and on the Little Elk river. Therefore it should not, probably, be regarded as representative of the original layers of sediment, from which this rock has been derived by metamorphism. This lamination or foliation in the outcrops along the west shore at Pike rapids has a strike N. 20° E., with a dip 70° to 75° N. 70° W.*

* The site of the fort or stockade in which Lieut. Z. M. Pike and his men spent the winter of 1805-6, from which the

At Cash's rapids, about two and a half miles below Pike rapids, schist nearly like the foregoing occurs in low outcrops in the channel and on the west shore, rising two or three feet above low water.

About a quarter of a mile below the last, and probably in the north edge of section 17, Bellevue, rock almost exactly the same as at Pike rapids is seen in the east shore of the river along a distance of about fifteen rods, rising at the highest place, near its south end, fifteen feet above low water. Its lamination has a strike N. 25° to 30° E., and dips about 45° N. 65° W. Some twenty-five or thirty rods farther south, it again has a small exposure in the east bank, and forms an island which rises about eight feet above low water, and extends eight or ten rods from northeast to southwest, situated about a third of the way across the river from its east side.

Half a mile farther south, at the middle of Muncy's rapids, which are a quarter of a mile long, mica schist, filled with many large staurolite crystals, and sometimes also including small garnets, as at Pike rapids, extends about twenty-five rods along the east shore of the Mississippi, rising some eight feet above low water. This is on land of Isaac P. Lambert, in the north part of the S. W. ¼ of section 17, Bellevue. Its strike, nearly the same as at the last place, is N. 25° to 30° E., and its dip is about 60° N. 65° W. It has been slightly quarried for cellar-walls, etc., and lies in layers from three inches to one foot thick. This rock also juts up at many places in the adjoining channel of the river along a distance of fifty rods or more, rising two or three feet above low water.

About a half mile below the last, the same staurolitic mica schist outcrops at the west side of the river, having an extent of only a few rods, but rising steeply to a hight of fifteen feet or more above the river. This is on the land of Charles Gillpatrick, in the N. E. ¼ of the N. W. ¼ of section 32, Swan River. Its strike is N. 20° E., and its dip is about 70° N. 70° W. It contains occasional masses or bunches of white quartz; one noted being a foot in length. This is the most southerly exposure of the staurolitic schist, which thus has frequent outcrops for four miles along the Mississippi, at Pike rapids and southward. Its lithological characters are nearly uniform throughout this extent; and its lamination has a nearly constant strike and dip. Proceeding

rapids received their name, has been found by Mr. Nathan Richardson, of Little Falls, at a point on the west side of the Mississippi about fifty rods below these rapids, on nearly level land some fifteen feet above the river, and not over sixty feet from its shore at low water. This stockade was about thirty-eight feet square. At its northwest corner is a large pile of stones, doubtless used for a fire-place. The first settlers, twenty-five years ago, saw two of the bottom logs still remaining.

northward, we find this strike and dip continued in the cleavage of the slate at Little Falls and on the Little Elk river, but with a slight deviation of the strike to a more northeasterly course. Beyond these outcrops northeastward, the nearest exposure of similar rocks is the district of slate ledges at the Northern Pacific Junction and on the St. Louis river, a hundred miles to the east-northeast. There the cleavage strikes nearly due east.

The only remaining outcrops of these crystalline rocks beside the Mississippi in Morrison county are about a half mile south from the last, being at Blanchard's rapids, best exposed upon the west side of the river, on land of Allen Blanchard, in the S. E. ¼ of section 32, Swan River. Here ledges are seen at numerous places upon an area of twenty or twenty-five acres, but nowhere rising more than two to four feet above the general surface. The largest exposure beside the river is fully a hundred feet long and averages forty feet in width. This is uniformly a very hard, compact, dark dioryte. It has no staurolite crystals. It shows no lamination, but is very much divided by joints, which are from one or two inches to a foot apart and nearly vertical. Their two principal sets bear N. 75° W. and due N. Lumps of white quartz, up to six inches in diameter, occur in this rock; and a vein of it a foot wide was reported, but at the time of my observation was covered by high water. This rock reaches in occasional outcrops one or two feet above low water some three-fourths of the way across the river, which is here an eighth of a mile wide; but it has no exposures on the east shore. About ten rods west from the large outcrop beside the river, nearly the same rock, but much less divided by joints and somewhat finer-grained, is exposed upon a space about a hundred feet square, from which the covering of drift, with a thick growth of timber, was swept away about ten years ago by the sudden flood from a broken ice-gorge.

A stratum of rock, apparently belonging in the same group with the preceding, was encountered by the well of Mr. Calvin A. Tuttle, two and a half miles south from the last and close north of the mouth of the "main Two rivers." This well is about 23 feet above the Mississippi, which flows close at the east. Its depth of 50 feet was as follows: soil, 1½ feet; gravel, with pebbles up to six inches in diameter, 4 feet; "white stony clay," probably a marly till, 4½ feet; bluish till, 7 feet; apparently decomposed rock, of various colors and in irregular masses, with considerable kaolin in oblique layers, up to about six inches in thickness, 8 feet; and thence to the bottom apparently a decomposed hydromica schist, dug into 25 feet and bored into 4 feet deeper. At the time of excavation, which was done with pick and shovel, this rock was thrown out in pieces up to ten pounds in weight; but all these, within a few weeks, by exposure to air and rain, were crumbled to a powder. It had no staurolite crystals; but occasional quartz lumps, from three to ten pounds in weight, and one of fifty pounds, were found in it.

On the Swan river. Swan river, in the southwest corner of section 1, of Swan River township, about one and a half miles above its mouth, as reported by Mr. Samuel Lee, has a fall of nine feet in six rods, over a bed of rock closely like that of Pike rapids, one and a half miles east. He thinks this rock has no exposure in the banks, of which that on the northeast is low, while that on the southwest is about 40 feet high, being composed of gravel and sand.

At the Ledoux bridge on Swan river, in the S. E. ¼ of the S. E. ¼ of section 4, Swan River township, a dark, compact rock, in part slaty and in part resembling quartzyte, is exposed in the bed of the stream and forms the foundation of the bridge abutments. Specimens were obtained; but observations of jointing, cleavage, or lamination, were prevented by the high stage of the water. Several exposures of this rock are reported in the channel of the river within a quarter of a mile above and below this bridge.

West of Little Falls. In the S. E. ¼ of the N. E. ¼ of section 13, T. 129, R. 30, about one and one-half miles northwest of Little Falls, numerous outcrops of rock, rising one to five feet above the general surface, occur upon an area some thirty rods long from north-northwest to south-southeast, and ten to twenty rods wide. This rock is all massively crystalline, with no apparent lamination or cleavage. It is all quite dark, probably including much hornblende. In part it is fine-grained; but mostly it is about medium-grained, and in part is quite coarse. The last of these varieties is sometimes decayed and friable, but mainly this rock is very compact and hard, not readily splitting in any particular direction. No staurolite, garnet, nor pyrite crystals were observed. Nearly all the varieties of this rock, when long exposed to the weather, tend to exhibit crystals of a greenish mineral, a sixteenth to a fourth of an inch long; and by further weathering these are dissolved, leaving small cavities. Mica is rarely present; it was noted only in narrow veins, a half to one inch wide and of small extent. These ledges are on the east border of an area of till, which thence extends indefinitely westward. They are ten to fifteen feet above a grass-marsh, a half mile wide, which lies on the east and southeast, but are scarcely higher than the plain of modified drift which occupies the Mississippi valley eastward.

Near the fork of Little Elk river. The only other outcrops of the crystalline rocks known in Morrison county are in the N. E. ¼ of section 7, T. 130, R. 30, being between the north and south forks of the Little Elk river, about a quarter of a mile northwest of their junction. One of these ledges is crossed by the road some thirty rods west from the ford of the north fork. Thence the rock reaches about fifteen rods south, with a width of one to two rods; but northward its exposures extend fully an eighth of a mile, occurring frequently upon a width of five to ten rods. It is said to have no outcrops upon any of the streams of this vicinity. As this whole region is wooded, other outcrops may have escaped notice. The rock here rises in ragged knolls and small north-to-south ridges, three to eight feet above the general surface, which is 10 to 25 feet above the north fork. It is nowhere massively crystalline, like the dioryte at "the point" near Little Falls; but is a dark schist, having always a more or less distinct lamination, often irregular and contorted. Its strike is uniformly from northeast to southwest, or within five degrees of this; and its dip varies from vertical to 75° N. W. It has no slaty cleavage, and is all very compact and hard, with few joints. In color and texture it is nearly like some portions of the Little Falls ledges. So far as examined, it has no staurolite nor garnet crystals. In one place a specimen was obtained, holding numerous large pyrite crystals, but these are not generally noticeable. This dark rock sometimes becomes, by weathering, spotted with brown particles; and by further weathering these are dissolved, leaving a minutely pitted surface. Often the rock includes gray, apparently quartzose, lenticular masses, a half to one inch thick and four to twelve inches long, coinciding with the nearly vertical northeast to southwest lamination. It has been slightly quarried by Gilbert T. Smith for his mill, situated a half mile to the east.

Cretaceous beds.

At the mouth of the "main Two rivers" in Morrison county, Cretaceous beds outcrop in the west bank of the Mississippi river along a distance of a quarter of a mile, and in the banks of Two rivers for perhaps the same extent, being overlain by 10 to 30 feet of drift. About a sixth of a mile south from the entrance of Two rivers the lower part of the Mississippi bank to a hight of several feet is gray clay, from which many specimens of two species of lamellibranch shells have been obtained, the valves being united. One of these species is five inches long, 2¾ inches high, and 2¼ inches thick; it is a *Margaritana*, very nearly allied to *M. Nebrascensis*, Meek & Hayden, from which it differs in having no considerable depression or corrugation on the sides. The other is a species of *Unio*, almost certainly *U. Danæ*, Meek & Hayden; it is about 3½ inches long, 1½ inches high, and an inch thick. Some of the *Unio* specimens are remarkably elongated taperingly, resembling *U. subspatulatus*, M. & H. These are fresh-water genera. A lignitic layer occurs some three feet above the river along a few rods half-way between where these fossils are found and the mouth of Two rivers, showing occasionally a seam of lignite an inch thick, with nearly black clay and particles of lignite for several inches above and below. This layer of lignitic clay is also seen in the right or south-east bank of Two rivers along an extent of ten rods between 20 and 30 rods above its mouth, being about one foot thick and three to four feet above the water. The lignitic deposits indicate, like the fresh-water shells, that these beds were formed in a river or estuary.

Ten to twenty-five rods north from the mouth of Two rivers, the west bank of the Mississippi shows three to eight feet above the water an exposure of a gray, hard rock, as fine-grained as shale, with no marks of lamination, but in some parts concretionary and stained with iron-rust (limonite). The following analysis* of this rock by Prof. Dodge gives a remarkably large percentage of alumina, hardly equaled by any known rock or mineral; one of the analyses of beauxite stated in Dana's *Manual of Mineralogy* being the nearest found. "*Chemical series, No.* 83. A siliceous rock, to a great extent soluble in hydrochloric acid. The rock was analyzed as a silicate, and its composition found to be as follows: silica, 19.81 per cent.; alumina, 52.43; oxide of iron, 1.32; calcium carbonate, 1.64; soda, 0.44; water, 23.23; making a total of 98.87. In appearance this rock bears a considerable resemblance to compact gray limestone. Its hardness is a little less than that of limestone."

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* *Tenth annual report*, p. 210.

A perfect tooth of *Otodus appendiculatus*, Ag., was found by Eddie Young on a sand-bar of Two rivers about a fourth of a mile above its mouth. Other shark's teeth and fragments, belonging to various species, have been also found there and on the south branch of Two rivers near Holding's Ford in Stearns county, about eight miles distant to the southwest. These indicate that marine Cretaceous beds probably underlie the drift somewhere within the basin of the stream; though it is possible that they were wholly eroded by the ice, their fossils being now contained in the drift.†

Glacial and modified drift.

The rock-outcrops in Morrison county generally show glaciated surfaces, rounded and planed by the ice-sheet, but no glacial striæ were observed, these having been effaced by weathering.

The average thickness of the drift in these counties is probably about a hundred feet. In a former part of this chapter, treating of topographic features, the contour and material of the drift have been already described. A few additional notes will find place here, and the probable glacial movements and conditions attending the formation of these drift deposits will be briefly stated.

By far the greater part of the drift here has been brought from the northeast. It contains frequent boulders, small fragments and pebbles of the dark or reddish eruptive rocks and the red sandstone that occur in place on the shores of lake Superior. Most of the large boulders, however, and a good share of the pebbles, are granite, syenite, gneiss and crystalline schists, such as occur in place in central and northern Minnesota and upon a large area thence northward and eastward to the Laurentian highlands. The proportion of boulders present in this glacial drift or till from the northeast is always much greater than in the till of southern and western Minnesota, which was brought from the north and northwest. In many parts of these counties and of the region farther north and east, boulders are fifty to a hundred times more plentiful than in the till from the northwest, spread over the prairie portion

† Compare with the Cretaceous fossils and masses of Cretaceous shale found in the glacial drift at Lime Springs, Iowa. less than five miles from the south line of Fillmore county, Minnesota, as described by Dr. C. A. White in *Proc. Amer. Assoc. for Adv. of Science*, 1872, vol. xxi, pp. 187–192. Among the numerous fossils there gathered were shark's teeth, closely like *Otodus appendiculatus*, Ag.; bones, teeth and scales of teleost fishes; *Ammonites* (two species); *Ostrea*, *Inoceramus*, etc. Of this collection Prof. O. H. St. John remarked: "That they are very late Cretaceous forms there can be no doubt, from the fact of their close relationship to the teeth found in the Eocene of the Old World." Dr. White regards them as upper Cretaceous, "as late as any yet recognized in any part of North America." See further, Dr. C. A. White, on later Cretaceous in Iowa, *American Geologist*, vol. i p. 221.

of the state. It is also a noteworthy fact that boulders are somewhat more numerous in the till forming the east part of the Red river valley plain, and on the higher land eastward, than farther south, as in the basin of the Minnesota river. Sand and gravel are also present in larger amount as components of the till in these counties and through northeastern Minnesota than in the till of western and southern Minnesota, brought from the northwest and derived in larger part from Cretaceous shales. In this respect, and in its abundant boulders, the northeastern till resembles that of the New England states.

Limestone boulders or even pebbles are absent or very rare in all the drift deposits on the east part of these counties. Not one was found in a careful examination of three miles of the shingle beach on the northwest shore of Mille Lacs. The most eastern locality in this district where limestone gravel was observed as a considerable component of the till, was in an excavation at Young Brothers' mill, near the mouth of Two rivers. Its occurrence there shows that during some part of the ice age a glacial current from the northwest here mingled drift brought from the region of the Red river and lake Winnipeg with the northeastern drift. Yet the latest ice-flow upon all western Morrison county evidently came from the north and northeast, for scarcely any limestone can be found among the boulders and pebbles of the till on the surface in that part of the district, not averaging one in five hundred. The modified drift on the Crow Wing river and thence southward through Morrison county has a somewhat greater proportion of limestone gravel, contributed by glacial streams poured down from the melting ice-fields upon a large area toward the northwest.

Examination of the pebbles forming the shingle beach on the northwest side of Mille Lacs shows them to be as follows: dark trappean rocks, nearly all fine-grained, with rarely one of coarse-grained dioryte, and a few of somewhat slaty appearance, together about half of all; reddish, mostly finely crystalline felsyte rocks, not often porphyritic or coarsely crystalline, nearly a fourth part; dull red sandstone, also nearly a fourth part, the foregoing three groups, which are plainly referable to the region of lake Superior, making together nineteen-twentieths, or more, of the whole; while the remainder are granite, syenite, white quartz, and occasionally a pebble of nearly white sandstone. No limestone, shale, distinct slate, nor conglomerate, was seen.

Such examination of the pebbles and rock-fragments on the northeast shore of lake Alexander shows about a third of all there to be granite, syenite and gneiss; about a third, dark trappean rocks, varying to dark, evidently sedimentary rocks with slaty look but only very rarely having a distinct cleavage; about a fourth part reddish crystalline felsytes, with some of red sandstone; a few of white quartz; agates, rare; limestone pebbles, perhaps one in three hundred, occurring only in small pieces, three to four inches long or of less size; no conglomerate.

The modified drift of the Mississippi valley was similarly examined where the river-road crosses Hay creek near the south line of Swan River township. About one in two hundred of the pebbles is limestone; a hundredth part is red sandstone; the remainder, nearly 99 per cent. of the whole, are dark greenish or brownish trap, reddish and gray granite, syenite, and other crystalline rocks.

In my work of mapping the belts of morainic drift through Morrison, Stearns and Todd counties, in 1880 and 1881, much valuable aid was contributed by Dr. Thomas M. Young, of Minneapolis, then living in Royalton, whose observations covered considerable portions of these counties, and who had studied out the nature and probable origin of these remarkable drift deposits, as early as 1873, regarding them as terminal moraines.

When the ice-sheet of the last glacial epoch was gradually melting away and retreating northward, its boundary was driven back by successive steps or stages of recession, being in northern Stearns county and the south part of eastern Morrison county at the time of the formation of its seventh or Dovre moraine. This seems to be represented by the drift hills in northeastern Stearns county east of Spunk brook and opposite the mouth of the Platte river. It probably includes a part of the morainic hills a few miles east and southeast of Little Falls; and its farther course eastward may be found in the region about the sources of the West branch of Rum river and of Hillman brook.

At the time of the eighth or Fergus Falls moraine, the lobate southern border of the ice-sheet appears to have accumulated the moraine on the western boundary of Morrison county, lying mostly in Todd county; its continuation eastward by the south side of lake Alexander to the Mississippi river; the moraine east of the Mississippi in Moorville, Belle Prairie and Little Falls; and its farther extent, bending to the northeast and passing along the upper Platte river, to the northwest side of Mille Lacs.

At the time of the ninth or Leaf Hills moraine, the ice-sheet had probably withdrawn from this district, excepting in a part of northwestern Morrison county, where this moraine seems to be represented by the prominent drift hills north of Shamano lake and lake Alexander, blending in part east of lake Alexander with the preceding. The continuation of the Leaf Hills moraine northeastward is a belt of conspicuously hilly drift in Cass county, extending from Sylvan lake, between Pillager and Gull River, north and east by Gull lake, the west side of Pelican lake, Cross lake and the east half of White Fish lake, to Crooked lake.

The deposition of the modified drift in these counties took place mostly, as elsewhere, while the ice-sheet was retreating. The rivers flowing from the melting ice-fields brought the gravel, sand and clay of these stratified beds. Such coarse sediments of gravel and sand as were deposited by the glacial rivers in their ice-walled channels or among masses of ice near the edge of the ice-sheet, constitute the osars and kames. Much gravel and sand, and all of the clay and fine silt of these rivers, were carried beyond the ice-margin and spread with a flat or only moderately undulating surface along the courses by which these waters flowed onward in their descent to the ocean. The thickness of this modified drift, when thus spread in smooth plains, is often only a few feet, though more commonly 20 to 40 feet, with till below.

Springs, depositing travertine in the form of "petrified moss," occur on the south side of Two rivers a quarter of a mile above Young Brothers' mill.

Wells in Crow Wing county.

Brainerd. R. K. Whiteley; in the town: well, 53 feet deep; soil, 1; fine sand, 20; whitish clay, 3 feet; coarse sand, becoming gravelly below, 25; and gravel, 4 feet, with water. This layer of clay about twenty feet beneath the surface, underlies nearly the whole town-site. Some wells get a permanent supply of water above this; but better water is obtained by wells of similar depth with the foregoing.

Henry Harman; sec. 28, three and a half miles east of the town: well, 50 feet, all till, yellow and reddish, very hard; never-failing water seeps in the lower part of the well, becoming ten or fifteen feet deep.

Crow Wing. Benjamin Shontell; sec. 2: well, 7 feet, all sand; water soft, about the same as rain-water. This is about 50 feet above the Mississippi river, which flows within an eighth of a mile on the northwest.

Wells at the old town-site of Crow Wing are 20 to 30 feet deep, all sand and gravel.

Moorville. S. M. Putnam; S. W. ¼ of sec. 2: well, 12 feet; dark soil, 1; sand and fine gravel, 11; three feet of water, inexhaustible.

W. B. Lovejoy; N. E. ¼ of sec. 23; well, 16; soil, 2; sand and gravel, 14 feet and continuing deeper; water of excellent quality, hard.

Daniel S. Mooers; sec. 27: well, 23 feet; soil, 2; sand and coarse gravel, 21; four feet of water.

T. 144, *R.* 30. T. P. Russell; N. W. ¼ of sec. 10: well, 31 feet; soil, 2; yellow and reddish till, 29; hard, requiring to be picked, containing a layer of sand about six inches thick fifteen feet below the surface, and others one to three inches thick below; water comes in all these layers of modified drift, standing usually six feet deep; it is soft water, nearly as good to wash with as rain-water.

Thomas Wadham; N. W. ¼ of sec. 11: well, 36 feet; soil, 1; all below is yellowish and somewhat reddish till, requiring to be picked, containing many stones and pebbles and a large proportion of sand; soft water seeps near the bottom, becoming five feet deep.

T. 144, *R.* 28. David S. Borden; S. W. ¼ of sec. 2: well, 18 feet; soil, 1; gravel and sand, 16; and till, dug into 1 foot; water soft as rain. Till forms the surface twenty rods west and ten rods north.

Wells in Morrison county.

Pierz. Frank Jaeger; S. E. ¼ of sec. 34, in the north part of the village: well, 40 feet; soil, 1½; gravel and sand, interstratified, including pebbles up to six inches in diameter, 20 feet; and dark gray till, 18½ feet and continuing below; water, becoming two feet deep, seeps from sandy veins at the bottom.

Mrs. Christopher Vernig; N. E. ¼ of sec. 8, in the south part of the village: well, 36 feet; soil, 1; gravel and sand, interbedded, with pebbles or cobbles up to a foot in diameter, 25 feet, and dark, very hard till, 10 feet; water rose from the bottom ten feet in one day.

Buckmantown. John L. Estey; N. E. ¼ of sec. 18; well, 26 feet; soil, 1½; all below was reddish till; water seeps, a plentiful supply.

Edward S. Arnold; sec. 20: well, 14 feet; soil, 2; reddish till, picked, 8; more sandy and softer till, shoveled, 4; water rose quickly four feet from the bottom, which was darker and very hard till.

Belle Prairie. Amos Clark; sec. 10, T. 42, R. 32: well, 18; soil, 2; sand and gravel, 14; and very hard gray till, 2 feet and below.

Andrew Hanson; N. E. ¼ of sec. 24, T. 41, R. 31: well, 27 feet; soil, 1; till, very hard, yellowish for the first three or four feet and dark bluish below, 25 feet, containing occasional layers of sand three to six inches thick; and gravel, one foot and extending deeper, from which water rose ten feet in one day.

William Harrison; sec. 34, T. 41, R. 31: well, 42 feet; soil, 1; sand and gravel, 5; yellow till, 14; blue clay, 1; and yellow till as above, 21; water rose in a few days to be twenty feet deep, and has remained at that level permanently during three years.

Wells in the village are 8 to 15 feet deep, wholly sand and gravel.

Little Falls. Wells in the town are 15 to 25 or 30 feet deep, all sand and gravel in the west part, but in the east part they go about ten feet into slate rock, there finding water. William Bredfeld's well is an example of those which are all modified drift; this was mainly sand, with some layers of gravel, containing cobbles up to a foot in diameter, to water in gravel at the depth of 25 feet.

The two following are in the part of this township west of the Mississippi river. E. E. Glass; S. W. ¼ of sec. 12: well, 28 feet; soil, 2; till, 26, yellowish above and reddish below, spaded for the first six feet, beyond which it was very hard, requiring to be picked; no clear sand or gravel, except at the bottom, where water was found in a vein of gravel, from which it rose fifteen feet in two days.

William Sly; sec. 30: well 15 feet; soil, 1; yellow till, picked, 14; water came in this till at the bottom, rising three feet in three hours; is hard water, but a majority of the wells in this neighborhood have soft water.

Bellevue. Peter McDougall; sec. 29, on the Mississippi valley plain, about 50 feet above the river: well, 47 feet; soil, 2; fine gravel and sand, becoming coarser below, 45 feet, to water.

Thomas M. Young; Royalton village: well, 18 feet; soil, 2; coarse gravel, 5; sand, 4; hard yellow till, picked, 7; water rose three feet from sand at the bottom.

The two following are in the east township of Bellevue. Peter McDougall, jr.; sec. 16: well, 20; soil,2 ; and red, very hard till, 18.

John S. Bouck; sec. 17: well, 47 feet; soil, 2; hard, red till, 44; gravel and quicksand, 1 foot, with water, not rising.

Green Prairie. Wells on the river-road go 15 to 25 feet in stratified sand and gravel, finding no clay. The largest cobbles encountered are about a foot in diameter.

Jeremiah Barnhart; sec. 6, T. 130, R. 30: well, 22; soil, 1; yellow till, picked, 10; caving sand and gravel, 10; and till below, dug into only foot; water plentiful, soft.

Swan River. A. K. Miller; N. W. ¼ of sec. 4: well, 28 feet; soil 2; yellow till, 6; reddish till, 20, both requiring to be picked; no layers of sand or gravel; water seeps from a sand vein a foot thick and about two feet wide, at the depth of twenty-six feet.

Frank X. Ledoux; S. E. ¼ of this sec. 4: well, 12 feet; soil, 2; gravel, 3; and sand 7. This is alluvium of the Swan river which flows near.

William H. Thompson, S. W. ¼ of sec. 8: well, 23; soil, 2; yellow till, 21, enclosing occasional sandy layers one to six inches thick, but no water; at the bottom water came in a sandy vein, and rose four feet in a few hours.

C. W. Lakin; S. W. ¼ of sec. 32 in the southeast part of the township, near the Mississippi river: well, 26 feet; soil, 2; yellow till, mostly spaded, 9 feet, with occasional sandy layers one to six inches thick; coarse gravel, 1 foot, yielding considerable water; harder blue till, also having occasional sandy streaks, 12 feet; and gravel and sand, with water rising from it a few feet, dug into 2 feet and extending deeper. Two pieces of wood were found in the compact blue till of this well; the first, six inches long and an inch thick, was at the depth of twelve feet, just beneath the layer of gravel; and the second, which projected into the well from the side and was broken off, was at the depth of eighteen feet, the part obtained being eight inches long and two in diameter.

Two Rivers. Isaiah L. Foster; sec. 2: well, 20 feet; soil, 2; a hard, ferruginous, gravelly layer, 8 inches; sand and fine gravel, with quicksand at the bottom, 17; water hard, plentiful and good.

George Geissel; North Prairie village: well, 65 feet; soil, 1½; loamy gravel, 2; and sand with occasional layers of fine gravel, 61½ feet; water comes in fine gravel at the bottom.

Parkerstown. Wells in this township are 10 to 30 feet deep, in till.

Culdrum. Allus Kurgel; S. W. ¼ of sec. 34 in the north township: well, 32 feet; soil, 1; very hard reddish till, 29; and darker, bluish till, 2 feet and deeper; water seeps, failing in dry seasons. A piece of wood, in texture resembling white pine, was found in this very hard till at the depth of twenty-five feet, projecting into the well from the side, so that a part of it one and a half feet long and two or three inches thick was chopped off.

G. W. Pancake; S. W. ¼ of sec. 12 in the south township: a cellar dug five feet deep goes into very hard, red till, which can only be excavated by picking.

MATERIAL RESOURCES.

The excellent supply of timber, and the agricultural capabilities of this district have been treated of in an earlier part of this chapter. Water-powers, quarrying, and brick-making remain to be noticed.

Water-powers in use, and dams for lumbering purposes, at the time of this survey, in 1881, were as follows:

On the Skunk river, Theodore Kasper's grist and saw-mill, two miles northeast from Pierz or Rich Prairie, with eight feet head; and Wilhelm Berg & Sons' saw-mill in the N. W. ¼ of section 30 in the south township of Pierz, with seven feet head.

On Hillman brook and its branches, dams to supply water for log-driving; one on Black brook, a tributary from the east in T. 41, R. 28, about twenty rods above its mouth, with seven feet head; the uppermost on Hillman brook, about thirty rods above the mouth of Black brook, having eight feet head; the second, about a mile down the stream, also having eight feet head; the "big dam," some two miles farther down, in section 35, T. 41, R. 29, having nine feet head; the Estey dam, three or four miles below the last, having six feet head; and one on the Little Hillman brook, three-fourths of a mile above its mouth, having seven feet head. From these dams the water is drawn away to raise the stream at time of low water. Several other dams on this brook, built to make the water a few feet deeper where boulders obstruct the channel, but not provided with gates for drawing water from them, are called "roll dams."

On the Platte river are two or more dams for lumbering, and Gravel & Goulet's mill at Gravelville for sawing and planing lumber and manufacturing flour, with about six feet head.

On Spunk brook, the North Prairie flouring mill in the N. W. ¼ of section 27, Two Rivers, owned by Geissel & Zeis, having sixteen feet head; three run of stone.

On Two rivers, in section 8, a fourth of a mile above its mouth, the Two Rivers flouring mill, owned by Young Brothers, having twenty feet head; Calvin A. Tuttle's lower saw-mill, in the S. E. ¼ of section 7, a half mile above the last, having eight feet head; and his upper saw-mill, on the north branch in section 14, Two Rivers, having nine feet head.

On Swan river, in the east edge of section 12, a third of a mile above its mouth, the Swan river flouring mill, owned by Samuel Lee & Sons, having eleven feet head, flowing back a fourth of a mile and an unused fall of nine feet in a few rods in the southwest corner of section 1, one and a half miles above the mouth of the river.

On the Little Elk river are Henry S. Hill's saw- and grist-mill near its mouth, having twelve feet head, flowing back about one and a half miles; and Gilbert T. Smith's saw- and shingle-mill in the west part of section 8, T. 130, R. 30, having seven feet head, flowing back a half mile.

Other good water-powers wait to be employed on these streams, and on the Nokasippi, and especially on the Mississippi river at Little Falls and Pike rapids.

Building stone. The outcrops of rock in Morrison county, described in the preceding pages, have been slightly quarried at several localities. The most promising seems to be the granite seen a short distance south of Fish lake, some three miles southwest from Rich Prairie. Drift boulders are considerably used for rough masonry.

Bricks. When Fort Ripley was built, the bricks required were made on the west side of the Mississippi river, near the fort. They are red and of good quality.

In 1879 brick-making was begun by William Schwartz on the east side of the Mississippi a mile northeast from Brainerd. His product in 1880 was about 2,000,000, and in 1881 about 4,000,000, half of them being used in building the Northern Pacific railroad shops in Brainerd, and many of the remainder by other builders in that city, while some are sold in Duluth and along the Northern Pacific railroad west to Dakota. The price is $10 per thousand, loaded on the cars. Jack pine, quite pitchy and well adapted for brick-burning, costs $2 per cord. A branch railroad, one mile long, is built to this brick-yard. The excavation for clay is beside the Mississippi river, which is here bordered by a nearly level plain elevated about 55 feet above ordinary low water. At the top, 10 to 15 feet of sand is removed; next is a bed of horizontally laminated, dark bluish clay, 25 feet; then similar clay, free from gravel but showing no lines of lamination, 10 or 15 feet, to the water-level. The whole section is modified drift. All this clay is very "strong," requiring in brick-making an intermixture of one part of sand to two of the clay. The bricks are cream-colored and of excellent quality. No fossils nor wood have been found in this excavation. The clay deposit has a large extent, being found by borings to reach nearly a mile along the river, with a width of a half mile. Its southwest end is near the cemetery, a half mile from the centre of Brainerd.

ARCHÆOLOGY.

On the northwest side of Mille Lacs, several aboriginal mounds, mostly of the ordinary dome-like form, but also including low embankments a few rods long, lie in a group on low land about a third of a mile from the lake-shore, being near the middle of the north side of the S. W. ¼ of section 12, T. 44, R. 28. The largest of these is ten feet high.

Some two miles eastward, in the edge of Aitkin county, the line between sections 5 and 6, T. 44, R. 27, intersects a group of eight or ten mounds, arranged in two lines from southwest to northeast, nearly parallel with the lake-shore, which is about thirty rods distant. One of these mounds is four rods long, one and a half rods wide and four or five feet high. The others are round or nearly so. Many fragments of Indian pottery are found by Mr. A. R. Nichols in his garden close by the shore of Mille Lacs in the west part of section 5 in this township.

Several low earthworks in oblong mounds or embankments three to four feet high, the most notable one extending three rods from north to south, were observed in Green Prairie township beside the road north of Fish lake, on land about ten feet above the lake, some forty rods east from the brook that flows into it.

Peculiar earthworks are found a half to three-fourths of a mile north of Little Falls, on the plain of modified drift east of the Mississippi river, elevated 27 feet above the river, being near the northwest corner of the village plat. They are described by Prof. Winchell as "low, circular ridges from eight to twelve feet across, rising but two or three feet above the general level. These are scattered over a small distance. . . . They may have been designed for habitation, having been formed at first by slightly excavating the surface of the ground, and then building rude arched coverings supported by wooden branches and enclosed by earth. As these decayed and fell in, the resulting forms would be exactly what are now seen. Beyond the limits of the village, further north, is an interesting ridge, nearly straight, running obliquely back from the river and a hundred and eight paces in length. This is of a very different nature, though plainly artificial. It is from three to four feet high. It has two low spots, or openings through it, which separate it into three main parts. It does not extend to the immediate river-bank, but is separated from it by an interval of several rods. The design of this ridge is not evident, but it must have had some relation to other works in the neighborhood. It may not, however, have the same age as the small circular ridges."

The following other localities of aboriginal mounds are described by Mr. Nathan Richardson. On section 35, T. 41, R. 31, in the south edge of Belle Prairie six miles east from Little Falls, nearly forty mounds are found around the shore of a lake, which was called by the Indians "the lake between the hills." A mile east from this lake is a group of about a dozen mounds, two of which were dug into a few years ago, a skeleton being found in each. "Going from these nearly south about two miles, on the point of dry land running down to the thoroughfare between the two Rice lakes, there are three mounds near together, much larger than these I have mentioned. Then by crossing the stream connecting the two lakes and following down the strip of dry land between them about half a mile, you come to the largest mound known in the county. It is about twenty-five feet in hight. Passing on about one mile, on the southwest bank of East Rice lake, eight or ten more of the smaller size are found. Occasionally one or two small ones are met with in other parts of the county."

Hole-in-the-Day's bluff, one and a half miles northeast from Little Falls, described on a preceding page, has its name from that of a Chippewa Indian, a famous slayer of Sioux (Dakotahs) in the conflicts between these tribes, who was buried, in accordance with his request, on the top of this hill. The prospect from it is very beautiful, overlooking a wide extent of country in every direction, with the smooth Belle prairie and the Mississippi river at its foot on the west.

Chipped quartz in the modified drift. In the sixth annual report of this survey Prof. Winchell described and figured six implements of white quartz and chert, which were found, with many chipped fragments of white quartz, such as would be produced in the manufacture of implements, on the surface and through the upper three or four feet of the sand and gravel that form the plain of modified drift on the east side of Pike rapids, at Little Falls on both sides of the river, and at the mouth of the Little Elk river. Prof. Winchell writes: "These chips are all angular, some of them being as sharp as knives, and perfectly unwaterworn, and they occur in a waterworn deposit. They vary in thickness from that of paper, and the size of one's finger-nail, to one and two inches across, of irregular, angular forms. Almost no other coarse material is found in the surface sand in which they are found; and whatever there is, is waterworn and rounded. The chips are generally without evidence of designed form, and nearly all the angular pieces are also destitute of all evidences of artificial shaping, so far as their forms are concerned. Only a few pieces were found that seemed to show the work of careful chipping, and they are not perfect.

The most certainly chipped form found was taken at Little Elk river, but was of brown chert. . . . . . . If they are of human origin, the wonderful abundance of these chips indicates either an astonishing amount of work done, as if there had been a grand manufactory in the neighborhood, or an enormous lapse of time for its performance.

"There is one other source to which these chips can be referred. The veins of white quartz traversing the slate at Little Falls, from which these chips were originally derived, were observed in one instance (near the mouth of Little Elk river) to split into angular pieces similar to those taken from the surface sand of the plain, under the action of moisture and frost. This was seen at a point where the freshet water of Little Elk river had lately carried away the surface materials, laying bare a large area of the slate. The quartz of the vein, not having a mineral cleavage, yet had an irregular fracturing tendency which resulted in the disintegration of a considerable quantity of the vein. It is supposable that in some earlier history of the river, when it was large enough to cover the whole valley from the drift bluffs a mile east of Little Falls to the drift bluffs several miles west, this same disintegration under natural causes took place, and that by some means the fragments were distributed by the water of the river, perhaps by floating ice, over the flat on which they are found when it was the bottom of the river. This supposition meets with the following obstacles:

"1. There is no point throughout the whole region round about where the slate conveying these quartz veins rises to the level of the surface of this plain so as to be within the range of transporting agencies, whether of the water of the river or of floating ice, but the quartz veins are many feet lower than the flat on which the chips occur.

"2. During the high stage of water that formed the chip-bearing terrace, that plain itself was intact from side to side, the present river-channel, which is cut down to the slate and the quartz veins, not having been excavated.

"3. The chips seen at Little Elk river, resembling these supposed human remains, were in the bed of the river, and *under* the drift originally, even the unmodified glacier drift, while the transported chips are *over* the glacier drift and in a water-washed sand.

"4. If these chips were the product of natural disintegration and river distribution, they would be expected to show some attrition incident to the long period of wearing they had passed through. On the contrary, while embraced in a water-washed and rounded sand, or fine gravel, they are themselves not worn in the least.

"5. The quartz fragments, while mainly destitute of evidence of designed shape, do in a few cases appear to be imperfect forms of arrow-heads or of cutting or scraping instruments, and also have, along the edges, the appearance of having received repeated blows, and present small fresh surfaces of forced fracture.

"6. In gathering about three quarts of these chips, eight pieces were found that could be thought to have a designed form, and two of these are of brown chert and undeniably the product of human design.

"Some of these chips have been submitted to Mr. F. W. Putnam, curator of Peabody museum of archæology and ethnology, Cambridge, Mass. After an examination he says he has no hesitation in saying that he 'considers them identical with those known to be formed by the hand of man when making implements of stone.' One of the chert specimens he regards 'a finished implement.'"

The interest in these observations lies in their testimony of man's presence in this region during the recession of the last ice-sheet, the melting of which supplied the modified drift that contains these quartz fragments in its upper part. Further important evidence of this is afforded by the discovery by Miss Franc E. Babbitt of a stratum a few inches thick containing very abundant chipped quartz fragments, underlying twelve or fifteen feet of the stratified gravel and sand, and resting below on a few inches of sand, which passed downward into a coarse waterworn gravel, immediately overlying till. This was found in a gap or notch cut by drainage in the west edge of the plain of modified drift, 310 rods, very nearly, or almost one mile, north of the east-west road by Vasaly's hotel in Little Falls, being 10 rods west of the road to Belle Prairie, and 38 rods from the river.* In this connection it should be added that recent discoveries in the drift gravel near Trenton, New Jersey, by Dr. C. C. Abbott and others, have abundantly proved that men lived there in this closing stage of the glacial period.

* Miss Babbit's observations and specimens are described in *Proc. Amer. Assoc. for Adv. of Science* for 1883, vol. xxxii, pages 385–390; and in the *American Naturalist* for June and July, 1884, vol. xviii, pages 594–605 and 697–708. Also see notes on these specimens by Mr. F. W. Putnam in his report for 1883 as curator of the Peabody museum, and in the *American Naturalist*, vol. xviii, p. 555.

CHAPTER XXIII.

THE GEOLOGY OF MILLE LACS AND KANABEC COUNTIES.

BY WARREN UPHAM.

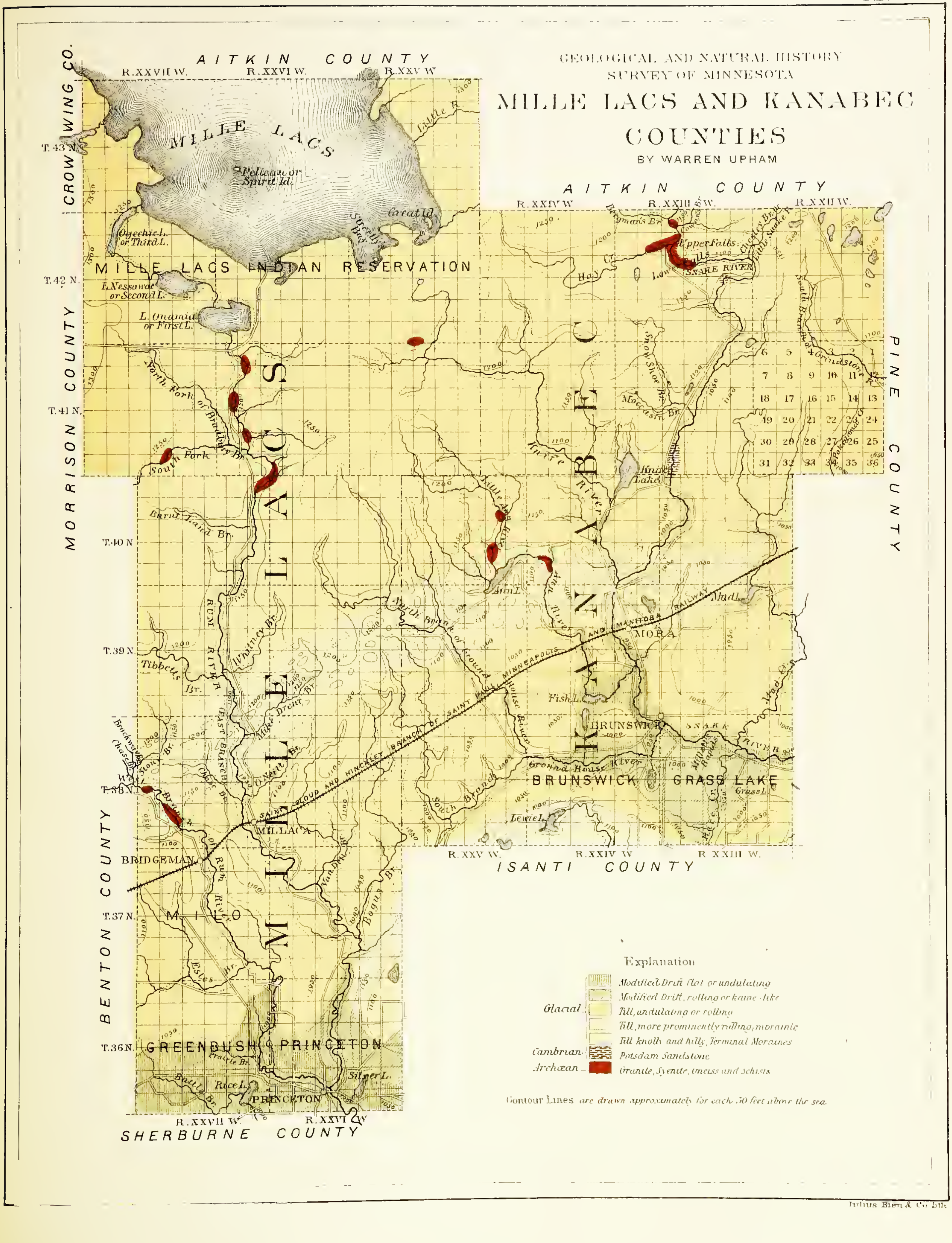
Situation and area. Mille Lacs and Kanabec counties (plate 54) are in the east central part of Minnesota. Princeton, the county seat and largest town of Mille Lacs county, is about 45 miles north-northwest from Minneapolis and St. Paul. Brunswick, the county seat of Kanabec county, is 23 miles northeast from Princeton.

Mille Lacs county is 47 miles long from north to south. In its northern eighteen miles it has a width of three townships, but farther south its width is only two townships or twelve miles. The area of Mille Lacs county is 688.19 square miles, or 440,443.18 acres, of which 74,945.53 acres are covered by water.

Kanabec county has a length of five townships, about thirty miles, and a width of three townships or eighteen miles. Its area is 541.99 square miles, or 346,872.30 acres, of which 9,336.41 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Mille Lacs county derives its name from the large lake crossed by its northern boundary, to which this name, signifiying "Thousand lakes," was given by the early French explorers. This lake is the source of the Rum river (a translation of its Chippewa name), which thence flows southward through the entire length of the county, receiving the drainage of nearly all its area. The exceptions are a narrow tract upon its east side, which is drained eastward by the head-streams of Knife, Ann and Ground House rivers, tributaries of the Snake river; and the south part of Greenbush,


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
MILLE LACS AND KANABEC
COUNTIES
BY WARREN UPHAM
AITKIN COUNTY
CROW WING CO.
MORRISON COUNTY
BENTON COUNTY
SHERBURNE COUNTY
ISANTI COUNTY
PINE COUNTY
MILLE LACS
KANABEC
MILLE LACS INDIAN RESERVATION
BRUNSWICK
GRASS LAKE
GREENBUSH
PRINCETON
MILO
MORA
MILLACA
BRIDGEMAN
Explanation
Glacial
Modified Drift, flat or undulating
Modified Drift, rolling or kame-like
Till, undulating or rolling
Till, more prominently rolling, morainic
Till knolls and hills, Terminal Moraines
Cambrian
Potsdam Sandstone
Archæan
Granite, Syenite, Gneiss and Schists
Contour Lines are drawn approximately for each 50 feet above the sea.
Julius Bien & Co. lith.

which is drained southward by Battle brook to the St. Francis and Elk rivers. Numerous small streams are tributary to the Rum river in Mille Lacs county, the largest from the east being Bogus brook, and from the west Bradbury and Tibbetts brooks and the West branch. Estes brook is an important affluent of the West branch in the south edge of Milo township.

The Snake river (a translation of its Chippewa name, Kanabec, which is pronounced with a heavy accent on the middle syllable) flows from north to south and then east through Kanabec county, draining nearly its whole area. A small tract on the northeast lies within the basin of the south branch of Grindstone river, a tributary of the Kettle river; and a few square miles in the south part of Brunswick send their surplus waters south to Stanchfield creek and the Rum river. The chief tributaries of the Snake river in Kanabec county are Chesley brook, or Little Snake river, and Mud creek on the east, and Knife, Ann and Ground House rivers on the west.

Lakes. After Red lake, Mille Lacs is the next largest included wholly within the limits of Minnesota. Its area is approximately two hundred square miles. In the first few miles of the course of Rum river southward from Mille Lacs, it flows through three lakes, each about two miles long. Thence southward for some thirty miles Mille Lacs county has only few and very small lakelets; but several of small extent occur in its southern part, the largest being Rice lake in southeastern Greenbush, and Silver lake a short distance east of Princeton, each about a mile long.

In Kanabec county lakes are more frequent, but not abundant, the largest being Knife and Ann lakes, each about two miles long, trending from northeast to southwest.

Topography. The contour of these counties varies from slightly undulating to rolling and in some parts moderately hilly. The elevations, however, seldom rise so high as 75 feet above the neighboring streams, and more commonly their hight is from 20 to 40 feet. Minor irregularities of contour turn the rivers and brooks in meandering courses, and the valleys are not deep enough to be important features in the topography. Details of portions which have been particularly examined are given in a later part of this chapter in treating of the geologic formations.

Elevations, Saint Cloud & Hinckley branch, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

	Miles from Saint Cloud.	Feet above the sea.
Estes brook, water, 1092; grade	22.0	1102
Bridgeman	25.0	1095
West branch of Rum river, water, 1058; grade	25.7	1078
Rum river, water, 1044; grade	27.9	1068
Millaca	28.1	1069
Bogus brook, water, 1043; grade	33.9	1076
South branch of Ground House river, water, 1020; grade	36.3	1048
Ground House	40.7	1042

	Miles from Saint Cloud.	Feet above the sea.
Ground House river, water, 1023; grade	41.0	1039
Ann river, water, 960; grade	45.3	1001
Snake river, water, 947; grade	46.9	981
Mud creek, water, 1003; grade	54.7	1015
Pokegama creek, water, 1013; grade	59.6	1025
Pokegama	60.2	1030
Little Pokegama creek, water, 1013; grade	62.8	1026
Hinckley	67.1	1032

Snake river and Mille Lacs.

Determined by the United States engineer corps, under the direction of Capt. C. J. Allen.

	Feet above the sea.
Cross lake at Pine City, and Snake river along a distance of sixteen miles to the foot of Millett's rapids, near the southeast corner of section 5, Grass Lake, held as nearly level backwater by the Chengwatana dam	937
Snake river at the old court-house of Kanabec county, in section 6, Grass Lake	940
At the Brunswick bridge, in section 1, Brunswick	941
Mouth of Ann river	943
At the road crossing one mile below the mouth of Knife river	958
Little Ann river on the road to Mille Lacs, two miles below the dam	1098
Highest land crossed by the trail from Snake river to Mille Lacs, about two and a half miles southeast from the lake	1299
Mille Lacs, ordinary stage of water	1251
The highest stage of this lake, five feet above the lowest, is	1253.7

The highest land of Mille Lacs county, in its northern townships, is about 1,300 feet above the sea; and its lowest land, where the Rum river crosses its south line, is about 1,000 feet. The mean elevation of this county is estimated to be approximately 1,200 feet.

The highest land of Kanabec county, in the west part of its northwestern townships, is 1,250 to 1,300 feet above sea-level; and its lowest land where the Snake river crosses its east line, is 937 feet. The mean elevation of Kanabec county is approximately 1,100 feet.

Soil and timber. Both these counties have a fertile soil, chiefly consisting of boulder-clay or till. Narrow areas of stratified gravel and sand, belonging to the modified drift, occur here and there along the larger streams; and this formation covers the south part of Greenbush and Princeton, and considerable portions of Brunswick and Grass Lake. In the two first named townships much of its surface was originally covered only by shrubs and few scattered small trees, being known as "brush prairie," and some of it was natural grassland, or true prairie, without tree or bush.

All other portions of this district, excepting small marshes, or rarely a sandy tract beside a river or lake, was originally heavily timbered. Clearings for farms have as yet removed only a slight fraction of this forest. The whole district, excepting Greenbush and part of Milo on the southwest, is more or less occupied by white, red and jack pines, black spruce and balsam fir. Of these evergreen trees the largest and far the most valuable is the white pine, great supplies of which have been cut during many years past on the Rum and Snake rivers and their tributaries. "Norway" or red pine is plentiful on the sandy and gravelly morainic drift hills in the northeast part of T. 39, R. 26, and also within six miles south of Mille Lacs. There is much jack pine (Pinus Banksiana) on the slightly undulating modified drift in the first two miles north from Princeton. Arbor-vitæ, commonly called "white cedar," occurs in swamps about the south side of Mille Lacs and eastward through northern Kanabec county. Red cedar is very rare, growing on the bluffy shores of lakes and rivers. Tamarack is abundant in swamps. Besides these coniferous trees, the following are also common or frequent, and make up a large part of the forest growth: bur, white and black oaks, sugar maple, box-elder, basswood, white and red elms, poplars, black and green ash, butternut, bitter hickory, ironwood, and yellow and canoe birches. Soft maple, white ash and cottonwood occur rarely.

Among the shrubs are frost grape, Virginian creeper, climbing bitter-sweet, staghorn and smooth sumach, prickly ash, hazel, low birch, alder, and willows. The wild fruits and berries include the American plum, black cherry, small red cherry, sand cherry (near Princeton), black haw or sheepberry, high bush cranberry, prickly and smooth gooseberries, black and red currants, red and black-cap raspberries, high blackberry, dewberry, low blueberries, cranberries, and strawberries.

GEOLOGICAL STRUCTURE.

Archæan rocks. At Stony Brook dam, on the West branch of Rum river near the centre of section 19, T. 38, R. 27, fifteen and a half miles in a straight line northwest from Princeton, and about three-fourths of a mile east-southeast from Brown's lumber camp and the mouth of Stony brook, the excavation at the north end of the dam shows a small exposure, about twenty-five feet across, of the same coarse, reddish syenite as occurs at and near the "roll dam," situated a little more than a mile farther west, in Alberta, Benton county. This has a smooth surface, nearly free from joints. Its hight is only one or two feet above the river.

In section 29, T. 38, R. 27, this rock occurs at many places in the banks and channel of the river along a distance of more than a half mile. These ledges begin about a mile southeast from the Stony Brook dam. The following notes describe them in the order that they were found in following down the river.

The first outcrop noted, perhaps below some which were not seen by me, occurs on the west or right side of the stream; and is about fifty feet square, reaching from the bank nearly across the river, which through this section varies from two to four rods in width, and is from three to six feet deep. It here has a fall of one foot, and the rock rises one to two feet above it. This is a massive syenite, coarse-grained and reddish, indistinguishable from that at the "roll dam."

At about twenty-five rods and again at thirty-five rods from the preceding, down the stream, which here flows south, ledges of the same rock are exposed in the left bank of the river, at each place having a length of about twenty-five feet and a hight of three or four feet.

Some twenty rods south from the last, where the river turns east, its right bank just below the bend has an outcrop of the same rock, extending four rods and rising five or six feet above the water. A part of this ledge is divided by east-to-west joints, one to two or three feet apart; but the higher southern part, like most of these outcrops, is massive, rarely intersected by joints.

About forty rods below the last, southeasterly, the river flows, falling about one and a half feet, over ledges of the same rock, in part divided by east-to-west joints. In the east or left bank these outcrops rise six feet above the water. Low exposures of this rock continue in the left bank about eight rods south, and after an interval of four or five rods again appear in the left bank for about fifty feet, rising seven feet above the river.

Twenty rods down stream, south-southwest from the last, ledges of the same rock re-appear in the left bank, and reach ten or twelve rods west-southwest, down the stream, rising five to eight feet above it.

Some ten rods below, westerly from the last, it is again exposed in the left bank at a small island.

From twenty to forty rods farther down the stream, westerly to where it turns south, then flowing south and southeast, there are frequent outcrops of the same rock at each side of the stream, above which these ledges rise from one to five feet. No exposures of rock are known below this on the West branch of Rum river; and none were found elsewhere in this region, except as described in the banks and channel of this stream. The descent of the West branch in its course of about three and a half miles from the "roll dam" to the lowest of these ledges, is estimated to be about 25 feet.*

The numerous rock exposures seen along these three miles are remarkably alike in lithological character, being a coarse, flesh-colored or reddish syenite, with occasional particles of mica. It is well adapted to be quarried for ordinary masonry and building purposes; but it has not yet been worked because settlements have not extended into this district.

On the main Rum river, generally denominated the "East branch," the drift and topographic features are mainly like those described on the West branch. Its only exposures of the bed-rock are about thirty miles, in a direct line, north of Princeton, being six to ten miles south of Mille Lacs. Low outcrops of small area, seen in descending this stream at Rum river falls, in the S. E. ¼ of section 18, T. 41, R. 26, a half mile above the mouth of Bradbury brook, and at other points a few miles below these falls, are described by Norwood as syenite, hornblende rock, gneiss, granite, and greenstone. Another outcrop is reported at the "ledge dam," on the south fork of the Bradbury brook, three or four miles above its junction with the East branch.

In Kanabec county these crystalline rocks outcrop on Ann river in the vicinity of the Ann Lake dam; and on Snake river at and near its Upper and Lower falls which are situated in T. 42, R. 23, respectively one and a half and two and a half miles south from the north line of the county.

The Ann Lake dam is situated two miles below the mouth of this lake in the east edge of the S. E. ¼ of section 30, T. 40, R. 24. About ten rods south from the gate of this dam, is a rock exposure six or eight rods in length and width; but the rock does not appear here in the channel or bank of the river. Its next outcrop is some fifty rods down stream, southeast, being in the S. W. ¼ of section 29, at the southwest end of the "roll dam," extending ten or twelve rods beside the river, and about six rods in width. These outcrops rise five to ten feet above the river. Again, about thirty rods down stream,

* The adjoining land is moderately undulating till, varying from a few feet to thirty or forty feet above the river, well wooded, but with little pine. Its soil promises well for agriculture. The pineries which still remain upon the head-waters of the West branch begin several miles farther northwest, beyond the west line of Mille Lacs county.

south from the last and in the same quarter-section, or in the north edge of section 32, at a "breakwater," a ledge two or three rods in extent is found a few rods southwest from the stream, and six or eight feet above it, but not rising above the general surface. All these outcrops are on the southwest side of the river. They are all alike, being a light gray, rather fine-grained granite, somewhat decomposed next to the surface, so that it breaks with a crumbling fracture. In excavation by quarrying it would probably be found adapted for building purposes, with fair durability. Throughout these exposures it has a very uniform texture, with no noteworthy variation and no included veins. It is cut by joints from two to ten or fifteen feet apart.

Similar rock-outcrops are reported on the Little Ann river two to four miles west and northwest from the foregoing, in section 26, T. 40, R. 25, and probably in the S. E. ¼ of section 14, occurring at several places in the channel and banks of the stream; but not at its dam, which is in or near the S. W. ¼ of section 11.

The route taken in going to the Upper and Lower falls of Snake river was from Kettle River station southwesterly by the north side of Pine lakes to McClure's lumber camp, situated on the west side of Cowan's brook, in the N. W. ¼ of the N. W. ¼ of section 35, T. 43, R. 23. The logging-road which follows down Cowan's brook, at about two-thirds of a mile south from this camp, in the S. E. ¼ of section 34 of this township, a little north of the line between Aitkin and Kanabec counties, goes over a spot which is strewn with many blocks of a fine-grained, gray granite, containing black mica. This is doubtless the bed-rock here, at a little depth below the surface.

About a mile farther southwest, some forty rods below Mr. McClure's landing and a quarter of a mile above the mouth of Cowan's brook, probably in the N. W. ¼ of the S. E. ¼ of section 4, T. 42, R. 23, a medium-grained gray granite, with a little black mica, outcrops in both banks of Snake river and forms a short rapid. These ledges on the left shore extend about forty feet, rising only one or two feet above the water; but on the right bank, a short distance below, they reach a hundred feet or more, having a hight six or eight feet above the river.

An eighth of a mile farther south, a finely laminated, dark gray mica schist forms outcrops two or three rods long and six feet above the river, in each bank. This has a northerly dip, varying from 5° to 15°. It is traversed irregularly by veins, from one inch to one foot, and on the west bank from one to four feet in width, composed of coarsely crystalline light gray granite, which has crystals of white mica an inch long.

The head of the Upper falls of Snake river is about two-thirds of a mile south from the mouth of Cowan's brook, in the north part of section 9. The first noteworthy ledges beyond those last described are about twenty-five rods below, west-southwest from, the head of these rapids. Here the river flows ten rods westerly between walls of granite only thirty to forty feet apart, with a descent of two or three feet. This is called the "jaws of the Upper falls." The rock here is mainly gray granite, in part fine-grained, but more generally of medium or very coarse grain. It also encloses many veins and masses, from one to eight feet in width, of exceedingly coarsely crystalline granite, with flesh-colored feldspar, or of such feldspar alone; and these in some portions make up nearly half of the rock exposed. Veins of white quartz, up to one foot in diameter, are also present. In some parts this rock has a distinct but much contorted lamination, being thus changed to gneiss and mica schist. Joints, vertical and nearly horizontal or oblique, divide these ledges into blocks from one to five or ten feet in dimension. Because of this structure the channel eroded by the river is enclosed by zigzag, nearly vertical walls, which are 10 to 15 feet high. The same formation, with great lithological variety, reaches twenty to forty rods from the river on each side, and rises 25 to 40 feet above it; and extends with nearly continuous exposures a third of a mile or more along the river south and southwest to the foot of these falls, which is near the mouth of Hay creek, a tributary from the west. Similar rocks, including very coarse granite, occur also at the "roll dam" and at the "gate dam" on this creek, situated respectively three-fourths of a mile and one mile above its mouth. On the east side of Snake river, about thirty rods south of the "jaws of the Upper falls," the rock for several rods is darkish gray gneiss, dipping 30° to 40° S. Some twenty-five rods farther south, it is a medium-grained, light gray granite, containing both black and white mica, the former most abundant; this is a little northeast from a small island in the river, and about an eighth of a mile north from the foot of these rapids of the Upper falls. This granite by its color and texture promises to be a handsome and easily wrought building-stone. It has more extensive exposures one mile farther southeast along the Lower falls.

A quarter of a mile south from the last, an exposure of dark granite or gneiss extends about ten rods along the southwest bank of the river. It is divided by a conspicuous system of joints which dip about 45° southerly. No outcrop occurs here on the northeast or left bank.

About forty rods southerly from the last, an outcrop of medium-grained, flesh-colored granite forms a small rapid. It occurs in the channel and has small and low exposures on each shore.

The head of the Lower falls is about an eighth of a mile south from the last, being where the river bends eastward in the north part of section 16. Between the Upper and Lower falls, as also above and below them, the land is slightly or moderately undulating till, 5 to 25 feet above the river, which is from three to eight rods wide.

The Lower falls of Snake river lie in the E. ½ of the N. E. ¼ of section 16, T. 42, R. 23, and in the N. W. ¼ of section 15, reaching about three-fourths of a mile, in which the river flows east and east-northeast, falling some twenty feet in this distance by a succession of rapids, but having no great fall at any one place. Along this distance the river is bordered by abundant granitic ledges, roughly ragged, jointed and broken, but rarely vertical, varying from 10 to 30 feet in hight. These rock-outcrops reach twenty to forty rods or more from the river upon each side, and form several east-to-west ridges, an eighth to a fourth of a mile long, rising 25 to 40 feet above the river. They rise most steeply in the south or right bank of the river, owing to a general system of joints which dips about 60° southerly. Throughout this area the principal rock is a medium-grained, light gray granite, desirable for quarrying, like that found fifty or sixty rods south from the "jaws" of the Upper falls. This rock is usually divided by joints at intervals of five to ten feet; and it includes veins and masses of gneiss, mica schist, very coarse flesh-colored granite, and of feldspar; but these are far less frequent than at the Upper falls.

The place of the river's channel across this formation may have been determined by a stratum of dark, partly crumbling mica schist, which seems to be included in the granite. It is seen in each bank of the river along the central and east part of the Lower falls for a distance of a quarter of a mile; its best exposure is in the east part of this distance, where its strike is E. or N. 80° E., coinciding with the course of the river. The dip of this bed is about 75° S., and its thickness appears to be about one hundred feet. This schist encloses occasional seams of white quartz up to three and sometimes six inches in thickness, coinciding with the foliation.

Potsdam sandstone. Below these falls, the only remaining outcrops of rock on the Snake river in Kanabec county are sandstones, in part conglomeritic, which are believed to belong to the Potsdam period. No fossils were found in them. Their first exposure is about one and a half miles southeast from the Lower falls, being at O'Brien's camp, in the north part of section 23, T. 42, R. 23, where the river turns from a west to a south course. Here a dark red sandstone, divided throughout in layers from a quarter of an inch to two inches thick, is exposed in the river's west or right bank for twenty-five rods at and south from its sharp bend, seen at several places to a hight two to six feet above the water. Its best exposure is just below this, reaching twenty rods south-southeast, in the east bank of the river, forming a wall three to eight feet high. The general surface eastward is only about ten feet above the river, but it has no rock-outcrops. All this sandstone is divided into thin layers, which in many places show oblique bedding, varying five to ten degrees from the planes of stratification which, throughout, dip 10° to 20° E. N. E. It is further divided by irregular vertical joints, into pieces only six to eighteen inches long. At several places this rock includes many gravel stones, up to a half or two-thirds of an inch in diameter; these are mostly quartzose; and one of soft, red pipestone was found.

In the south part of the next township (41 of range 23), Shumard reports an exposure, twenty-five feet in thickness, of red sandstone and alternating ash-colored clays.

At Knife River bridge, which crosses Snake river in the N. E. ¼ of section 3, T. 39, R. 23, about three miles east-southeast from the exposures of granite near Ann Lake dam, this sandstone is exposed for a length of about 300 feet and a width of 75 feet, on the southwest or right shore of the river. It has mainly a sloping surface, rising from the water's edge to about five feet above it; but at its east end for nearly 100 feet it has a vertical outcrop, rising in its highest part seven to ten feet above the river. This rock is a coarse-grained sandstone, of gray and iron-rusted color, divided by weathering into layers from a quarter of an inch to one and a half inches thick. Mainly it has an eastward dip, which appears to be slightly variable in amount and direction. At one place, the steepest noticed, the dip is 15° E. S. E. In some layers this rock has a deep dull red color for three or four inches vertically through a length of six to ten feet. This entire outcrop encloses pebbles here and there, mostly quartz or quartzose, of all sizes up to three and a half inches in diameter, but they are nowhere so plentiful as to give the rock the character of an ordinary conglomerate.

Below this point the next exposures of rock on the Snake river are at Chengwatana in Pine county.

Glacial and modified drift. The outcrops of rock in these counties have a planed and rounded surface due to glaciation; but no glacial striæ were observed.

Probably the average thickness of the drift here is from 75 to 100 feet. It is mostly boulder-clay or till, brought from the northeast as shown by the material of the abundant boulders. This deposit has a gray color, with usually more or less of a reddish tint, due to the portion of its material which was derived from the red sandstone and shales in the region of lake Superior. The same reddish tint is also frequently noticeable in the beds of modified drift, which are chiefly gravel and sand. These are found occasionally enclosed in the till, being there the source of the water often obtained in large supply by wells; but they form more considerable portions of the morainic drift hills, interbedded there with deposits of till, or in the superficial knolly and ridged accumulations called kames. This modified drift is also spread with a nearly level or only slightly undulating contour in narrow belts bordering some portions of the rivers; and it constitutes the surface of large parts of Greenbush, Princeton, Brunswick and Grass Lake. Its hight above the streams in these townships and elsewhere is only 10 to 30 or rarely 40 feet.

Limestone boulders and pebbles are absent or very rare in the drift of this district, excepting on its southern edge, where their occurrence shows that a part of the drift there was brought by an ice-current from the west and northwest. In the excavation for the foundation of a steam-mill in Princeton on the east bank of the Rum river about thirty rods above the mouth of the West branch, very large slabs of limestone were found in the drift, and several tons of it were used for masonry.

Most of the large boulders throughout the district are granite, syenite and gneiss; about an eighth part are reddish felsitic rocks, metamorphic or igneous; and about a sixteenth part are dark trappean rocks.

A mass of drift copper, weighing about five pounds, was found by Mr. Benjamin R. Soule in the excavation at the north end of Stony Brook dam on the West branch of Rum river. Another piece of drift copper, weighing twenty-seven pounds, was found by lumbermen in 1878 in the channel of Chesley brook about one and a half miles from its mouth, near the north line of Kanabec county. Many smaller masses of drift copper, usually not exceeding a few ounces, have been found in digging wells and cellars, or on the surface. These, like the felsitic and trappean boulders, are referable to the lake Superior region, and demonstrate the northeastern origin of these drift deposits.

An examination of the gravel in the modified drift at Fish Lake dam on Ann river near its mouth, shows about equal representation of the four following groups, which together make up nearly all of the pebbles and cobbles: granites and granitic rocks; dull red crystalline rocks, occasionally amygdaloidal; dark trappean rocks; and light buff sandstone, like that which outcrops at Hinckley, in Pine county. Red compact felsite, or possibly in part jasper, red sandstone, and black slate or slaty rocks, are also present in less numbers. White quartz is very rare, and limestone is wholly absent. No conglomerate was seen here, but one piece, a foot long, of dark gray color, was observed in the till three or four miles farther northwest.

Mille Lacs is bordered in part by beaches of sand and gravel, which alternate with other parts strewn with many boulders, occasionally forming remarkable ridges. Such ridges of boulders are also found on many smaller lakes. They have been formed in some cases by the erosion of the till or boulder-clay, all its other portions being carried away by the waves; and in other cases, where the lake is shallow and its shore low, by the expanding power of ice pushing these blocks of rock from the bed of the lake to its margin. Col. Charles Whittlesey writes: "On the shores of Mille Lacs, which is at the source of the Rum river in Minnesota, and which is about twenty miles in diameter, there are very heavy lines of large boulders, rising five and six feet above water-level. There are also several small islands in this lake, at different distances from the shore, composed entirely of large boulders, generally more than two feet in diameter, which have accumulated in the same way with those on the shore. One of these has a hight of twelve or fifteen feet, wholly free of gravel or earth. They are from one to four miles from the shore, and in shallow water. The boulders are syenite, granite, trap, gneiss, etc., being the same with those which occur in the drift beds of the adjacent shore."* The most conspicuous of these small islands of boulders, situated about six miles east from the mouth of the lake and nearly four miles from the nearest part of the shore, is regarded by the Chippewa Indians of this region with superstitious awe.

Curious rolled masses of clay, which may be denominated clay-pebbles, were found by Rev. U. W. Small in the modified drift that forms the east bank of the main Rum river a half mile north of Princeton. This bank is 30 or 40 feet high, and consists of sand and fine gravel. The clay-pebbles occur plentifully in the lower ten or fifteen feet of this deposit, next to the level of the river. They are mostly elongated, spindle-shaped, somewhat in the form of sweet potatoes, and vary from three or four to eight or nine inches in length; but some of them are nearly globular, being two to three inches in diameter. Only one was found with a distinctly flattened form. The clay is jointed, as seen by breaking open these masses, the joints having an irregular course and being from a half inch to an inch apart. Very thin black films, probably manganese dioxide, occur on the jointage planes. Some of these clay-pebbles have gravel-stones from a fourth to three-fourths of an inch in diameter embedded in their sides, this gravel being larger than any in the deposit where they are found, showing that the masses of clay were rolled along over coarser deposits. About a half mile farther north Mr. Small found a bed of similar clay forming the lower part of the river bank; and his opinion as to the mode of formation of these remarkable pebbles of clay seems to be correct, namely, that the jointed structure of the clay permitted lumps to be dislodged by the eroding action of the stream, which in rolling them onward gave them their present shape. Since their formation considerable additional modified drift was deposited, covering both the bed of clay and the stratum that contains the clay-pebbles with several feet of fine gravel and sand.†

For the greater part the till of this district is moderately undulating or rolling, its elevations being 10 to 30 feet above the hollows, to which the descent is by smooth slopes. It has a distinctly morainic contour, in short and steep ridges and hillocks, grouped irregularly and enclosing here and there small marshes and lakelets, in the vicinity of Stony brook and along a belt a

* "On the Fresh-water Glacial Drift of the Northwestern States," in *Smithsonian Contributions*, 1864, pages 28 and 29.
† A notice of these clay-pebbles is given by Prof Winchell in *Proc. Amer. Assoc. for Adv. of Science* for 1883, vol. xxxii.

mile or so in width extending thence northeastward across the Rum river in section 2, T. 38, R. 27, and through T. 39, R. 26, in which it lies on the northwest side of Mike Drew brook and on the south side of Ground House river. This morainic belt continues eastward through Kanabec county, by Ann lake and across Ann river, to the Snake river, Spring brook and Mud lake. Its characteristic contour and material, small and irregular hills of till with very abundant boulders, rising 25 to 75 feet above the enclosed lakelets and the adjacent streams, are well seen on Ann river and on the east side of Snake river in the northeast part of T. 39, R. 24. From Rum river northeastward through T. 39, R. 26, this range is in part kame-like hills and short ridges, 50 to 100 feet high, composed of sand and very coarse gravel, with abundant cobbles up to one or two feet in diameter, but having few boulders of larger size. One of its highest elevations is Stony hill, in the N. W. ¼ of section 1, T. 38, R. 27, beside the Rum river lumber-road about three-fourths of a mile north from the mouth of Mike Drew brook.

The till containing limestone on the south edge of these counties probably belongs to the time of the fourth or Kiester moraine, when the ice-flow from the north and that from the west seem to have been confluent on that area. The morainic belt described in the preceding paragraph belongs apparently to the time of the fifth or Elysian moraine. It may also have been partly formed in the next halt of the glacial recession, when the sixth or Waconia moraine was accumulated. The seventh or Dovre moraine probably is traceable from the upper part of Hillman brook in Morrison county eastward through this district, passing south of Mille Lacs and across the northern part of Kanabec county. At the time of the eighth or Fergus Falls moraine, the ice-sheet seems to have wholly retired from these counties, its marginal accumulations being prominent in eastern Crow Wing county and the adjoining part of Aitkin county, on the northwest side of Mille Lacs, while east of this lake the lobate ice-border, curving to the south, formed a series of morainic hills of till, observed in the south edge of Aitkin county from the Snake river eastward to the Pine lakes, and thence extending northeasterly in Pine county toward Kettle River station. More full exploration of this region may result, however, in some better correlation of these moraines.

Wells in Mille Lacs county.

Princeton. Wells in the village are from 20 to 30 feet deep in gravel and sand, obtaining plentiful water of good quality but hard.

Asa Bullis; S. W. ¼ of sec. 12: well, 18 feet; soil, 1; all caving gravel and sand below, to water in quicksand. The water is hard, owing to the limestone in the drift of this vicinity. Within a mile to the south, till forms low swells, including among its boulders slabs of limestone up to ten feet in length.

Martin V. B. Cater; sec. 29: well, 20; soil, 1; sand and gravel, 19, to water in coarse gravel. The deep wells of this neighborhood, 20 to 30 feet deep, have hard water, especially during the dry season; but the shallow wells, 10 to 15 feet deep, are soft or less hard, some of them being considered as soft as rain-water.

Greenbush. Samuel Marshall; sec. 20: well, 22 feet; soil, 1; yellow till, 8; very stony till, 3; till as above, 2; sand, 1½ feet; very hard till, with much iron-rust, 5; and gravel, 1½ feet, with water, not rising. This is on a hill, some 30 feet above the general level of the sand and gravel which cover most of this south half of the township.

Milo. A. T. Chisholm; S. E. ¼ of sec. 22: well, 26 feet; soil, 1; reddish till, of the usual somewhat sandy character, very hard, all picked, 25 feet and continuing lower; water comes in crevices of the till in the last four feet and at the bottom, usually standing three to five feet deep, inexhaustible by the most rapid drawing. This is hard water, especially in the dry season; but the West branch of Rum river, which flows near by, is soft water, and so are some of the shallow wells of this neighborhood, only 10 to 15 feet deep.

Wells in Kanabec county.

Brunswick. Farm of Danforth Brothers & Bean, base of supplies for lumber camps on the upper Snake river and its branches; east edge of the N. E. ¼ of sec. 1: well, 22 feet; all caving gravel and sand; water nearly as soft as rain.

Peter Leaf; sec. 4: well, 25 feet; soil, 1; gravel and sand, 24.

Grass Lake. John A. Peterson; S. E. ¼ of sec. 14: well, 30 feet; soil, 1; yellowish and reddish till, picked, 27; quicksand, 2 feet and extending lower, with water. Grass lake, about a third of a mile in diameter, lies close southeast.

Benjamin Norton; sec. 18: well, 16 feet; soil, 2; clay, 4; sand and gravel, 10.

T. 39, R. 23. John L. Spence; sec. 8: well, 10 feet; soil, 1; yellow till, 8; and quicksand, 1 foot and continuing lower, with water.

John Hart; sec. 18: well, 23 feet; soil, 2; yellowish, quite gravelly till, 18; and sand, 3 feet and deeper; water, found in the stratum of sand, rose to a permanent level four feet above it.

A. De Wolf; S. W. ¼ of this sec. 18: well, 28 feet; soil, 1; sand, 6; coarser sand and gravel, 6; yellow and dark gray hard till, picked, 15 feet, also extending below.

T. 39, R. 24. Ann farm, Isaac Staples' base of supplies for lumber camps on the upper Ann river; N. E. ¼ of sec. 21: well, 39 feet; soil, 1; sandy and clayey silt, 6; yellow gravel and sand, with a reddish tint, 32 feet, to water in quicksand; it is considered nearly as soft as rain-water.

MATERIAL RESOURCES.

Lumbering is the leading business of this district; but the soil is good for agriculture, and many farms are being cleared and brought under cultivation.

Water-powers were employed for manufacturing in 1880 at the two Princeton flouring mills, owned by Allen & Sadley, on the West branch of Rum river close to its mouth and one and a half miles above, the lower with nine feet and the upper with eight feet head, each having two run of stone; and the Kanabec mills, on the Ground House river in section 12, Brunswick, owned by S. E. Tallman, sawing lumber and manufacturing flour, with head of about five feet.

A list of the dams used for maintaining a sufficient supply of water for log-driving, is as follows, chiefly on the authority of Mr. Leonard Pratt of Princeton and Mr. Duane Porter of Chengwatana.

On the Rum river, a dam having six feet head, three-fourths of a mile south of lake Onamia or First lake.

On Bradbury brook a dam of six feet one mile above its mouth; another of six feet on the north fork of this brook, three miles above the junction of the forks; the upper dam on the north fork, two miles above the last, also about six feet; and on the south fork three dams, respectively three, four and five miles above the junction of the forks, each having about six feet head.

On Tibbetts brook seven dams: one three-fourths of a mile above its mouth, seven feet; others at one and a half miles, four miles, and six miles from its mouth, each seven feet; the fifth, three-fourths of a mile above the last, eight feet; and the sixth and seventh, one and a half and four miles farther up the brook, each seven feet.

On Mike Drew creek, one of five feet head a half mile above its mouth; and another two miles farther up, with a head of six feet.

On Bogus brook, a dam six miles from its mouth, having six feet head; and a second, one and a half miles above this, having seven feet head.

On the West branch of Rum river are the Stony Brook dam, about three-fourths of a mile below the mouth of Stony brook, having nine feet head, a second, nine miles above this, having six feet head; and a third, four miles above the last, having eight feet head.

Snake river has a dam of nine or ten feet head on section 24, T. 42, R. 23, a few miles southeast from the Lower falls. Its upper dam, situated in Aitkin county, on the S. W. ¼ of sec. 21, T. 43, R. 23, has eight feet head.

Bergman's brook has a dam of five feet head a half mile above its mouth.

Hay creek, west of the Upper falls, has two dams, each of about six feet head.

Snow-shoe brook has a dam of seven feet head a mile above its mouth.

Knife river has two dams, one of seven feet just below the inlet from Knife lake, which it flows; and the Little Knife dam, in the north part of section 28, T. 41, R. 24, having seven feet head.

Ann river has two dams, namely, the Fish Lake dam, near the mouth of the river, with head of five feet; and the Ann Lake dam, with head of seven feet, in the S. E. ¼ of section 30, T. 40, R. 24, two miles below Ann lake, which it raises five feet.

Ground House river has a "big dam," with eleven feet head, in section 7, Brunswick, just below the junction of the north and south branches. Its north branch has two dams, each of about eight feet head; and the south branch formerly had a dam of six feet head.

Chesley brook, also called Little Snake river, has three dams; the first, a mile above its mouth, has seven feet head; the second, three miles from the mouth, ten feet; and the third, four miles above the last, five or six feet.

Mud creek has a dam just below the mouth of Mud lake, with about seven feet head; and another higher up this stream has a head of about five feet.

Building stone. The syenite on the West branch of Rum river, and the granite at Ann Lake dam and at the Lower falls of Snake river, will furnish good building stone, when the development of the region produces a demand for it.

Bricks. G. W. Dunton has made bricks since 1876 in the N. E. ¼ of sec. 21, Princeton, nearly two miles north of the town and about a half mile west of Rum river. His product in 1879 was 400,000, selling at $7 per thousand. These are red bricks of good quality. Sand is mixed with the clay for tempering in the proportion of one to three. The section of the well at this brickyard, 24 feet deep, is horizontally laminated clay, yellowish to a depth of 16 feet, and dark bluish for the next 8 feet; water rose four feet from sand and gravel at the bottom.

Jonas S. Scott & Son, living in the S. E. ¼ of section 12, Greenbush, began brick-making in 1879 in the S. W. ¼ of section 7, Princeton, close to the West branch of Rum river. Their product in 1879 and 1880 was about 120,000. The bricks are of dull reddish color, and are hard and durable. The clay requires an intermixture of half as much sand for tempering.

In Brunswick red bricks of fair quality have been made in small amount from the till, which is free from limestone and so sandy that it is suitably tempered for this use, by John Peterson in section 4, Andrew Olson in section 10, and Olaf Borg and F. K. Nilson in section 26.

Springs. Notably large springs occur along the course of Spring brook, in the northwest edge of T. 39, R. 23; and there is a copious chalybeate spring on land of Isaac Staples in the north part of section 21, T. 39, R. 24, on the west side of Ann river near the house of the Ann farm.

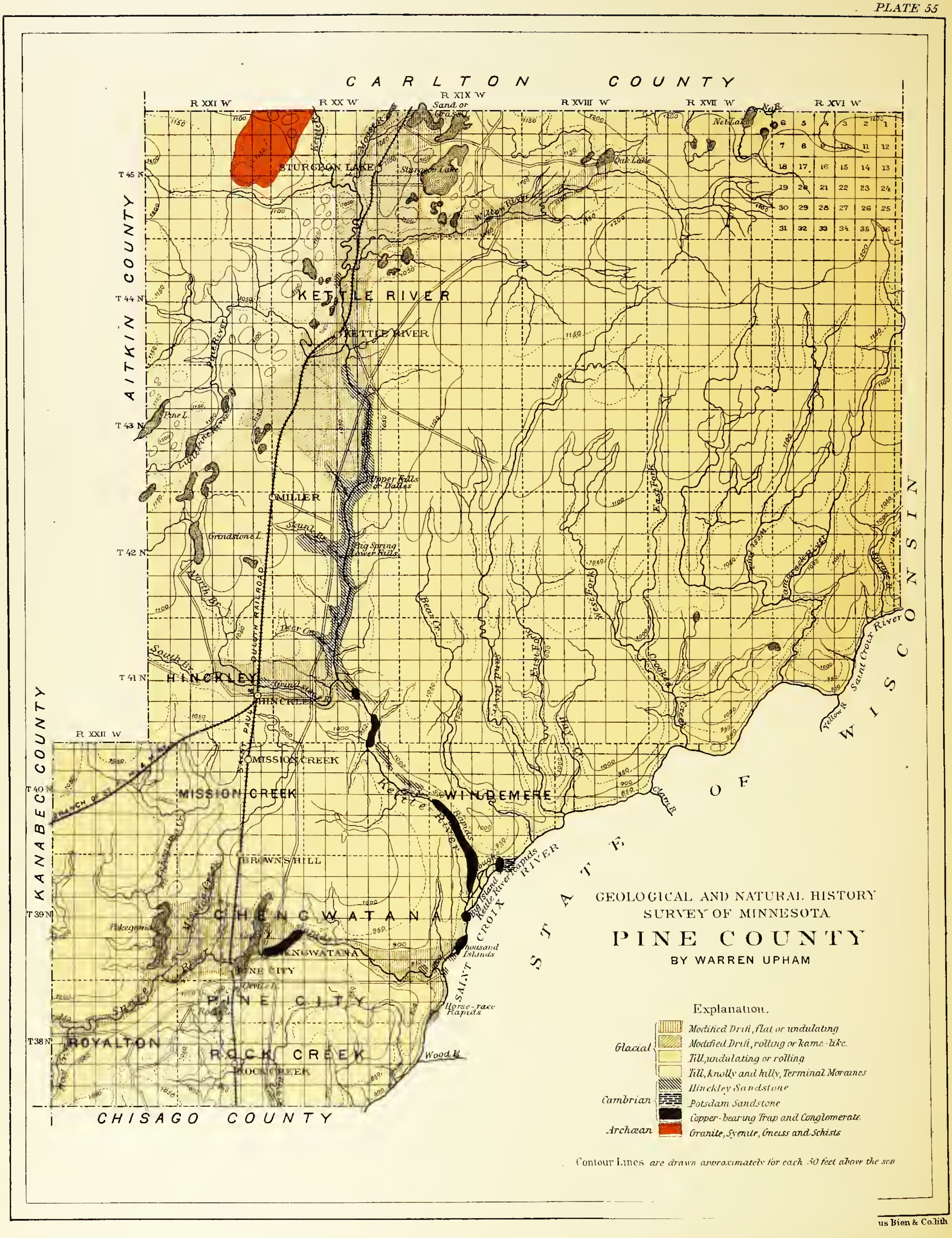
ABORIGINAL EARTHWORKS.

In section 25, Greenbush, on Mr. Samuel Marshall's land east of the north part of Rice lake, is a round mound about fifteen feet high, situated some fifteen rods from the lake-shore. Within thirty rods about this are twenty or thirty smaller mounds, two to four feet high. There is a tradition that three Dakota warriors, killed in a fight with the Chippewas, were buried in the largest mound. In plowing over this mound, the plow struck and splintered a log of wood enclosed in it near the surface.

On the east side of Snake river, opposite the mouth of Ann river, on land about 35 feet above the river and a quarter of a mile from it, are the earthworks of an "old Indian fort." Embankments, having a hight three to five feet above the bottom of a slight trench on their inner side, extend in an irregularly four-sided outline about nine rods long from northeast to southwest and five rods across the ends. It is supposed to have been the work of the Chippewas in their wars with the Dakotas, probably aided by the superintendence of some white man.

Twenty or more mounds of the usual dome-like form are situated on the north side of the Ann river about a half mile west from its mouth, being forty to sixty rods west from the Fish Lake dam. They are mostly from two to four feet high; but one, about seventy-five feet in diameter, has a hight of eight feet, with steep sides and flattened top.

On the southeast side of Fish lake, in section 34, are two mounds, each about ten feet high.



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CHAPTER XXIV.

THE GEOLOGY OF PINE COUNTY.

By WARREN UPHAM.

Situation and area. Pine county (plate 55) lies at the middle of the east border of Minnesota, adjoining Wisconsin, from which it is separated in part by the Saint Croix river. Pine City, the county seat and largest town, is sixty miles north of Saint Paul and Minneapolis.

The length of this county from north to south is 48 miles. Its northern half is 36 miles wide, but the width of its southern half decreases to 15 miles on the south boundary. The area of Pine county is 1,444.50 square miles, or 924,477.51 acres, of which 15,844.68 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Pine county lies wholly within the St. Croix basin, excepting a few square miles on its northeast edge, which are drained by the Nemadji river to lake Superior. The chief tributaries of the St. Croix river in this county, in their order descending the stream, are Spruce, Tamarack, Crooked, Sand and Bear creeks, Kettle and Snake rivers, and Rock creek, the last joining the St. Croix in Chisago county.

Kettle and Snake rivers are large streams. The former receives Moose and Willow rivers from the east and Pine and Grindstone rivers from the west. Mission creek and Pokegama creek and lake are important tributaries to Snake river from the north.

Lakes. Through most of Pine county only infrequent and small lakes are found; but they are abundant near its north side and on the west between Pine and Grindstone rivers, the largest of these being Sturgeon, Island, Oak, Pine and Grindstone lakes, from two to three miles long, trending from north to south or southwest. Two of larger size, namely, Cross and Pokegama lakes, each about four miles long from north to south and averaging a half mile wide, lie in the south part of the county. The Snake river touches the south end of Pokegama lake and flows through Cross lake.

Topography. Some portions of this county are nearly level or only slightly undulating, such being the contour of much of the tract of gravel and sand, belonging to the modified drift, in some parts three or four miles wide, which borders the Kettle river, and of a large area of till that extends east and southeast from the south end of Cross lake to the St. Croix valley. The opposite extreme of rough morainic hills and short ridges, consisting mostly of till, very irregularly grouped, rising 40 to 60 or 75 feet above the enclosed hollows and lakelets, is the contour of the southeast part of Royalton and the west part of Rock Creek and Pine City townships, reaching northeastward to the south end of Cross lake. Similar morainic hills border the Pine lakes, the upper Pine lake being in the southeast corner of Aitkin county, and continue from them several miles northeastward into the southwest part of Kettle River township. When the region east of the Kettle river is more fully explored, probably such belts of hilly drift will be found there, being continuations of those observed about the Pine lakes and farther to the south in Kanabec county. Besides these strongly contrasted types of contour, large areas of this county, probably three-fourths of its entire extent, are moderately undulating or rolling till, rising by gentle slopes 25 to 40 feet above the streams and the frequent marshes and tamarack swamps.

The St. Croix river on the boundary of this county flows in a valley a half mile to a mile or more in width, which it has eroded 75 to 150 feet below the average of the adjoining country. The Kettle river along a part of its course lies in a picturesque gorge, walled by bluffs of sandstone 75 to 100 feet high, described more particularly in a later portion of this chapter. Above Cross lake the Snake river has no considerable valley; but between this lake and its mouth its erosion is measured by bluffs that increase in hight from 50 to 100 feet.

Elevations, Saint Paul & Duluth railroad.

From profiles in the office of H. A. Swenson, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
South branch of Rock creek, water, 919; grade	58.8	932
North branch of Rock creek, water, 925; grade	59.4	938*
Summit, cutting 3 feet; grade	61.2	983
Cut, 33 feet maximum depth, only 300 feet long; grade	62.7	966
Opposite Devil's lake, filling 16 feet; grade	62.8	964

	Miles from Saint Paul.	Feet above the sea.
Pine City	63.6	949
Snake river, low to high water, 928 to 938; grade	63.7	949
Summit (Brown's hill), cutting 14 feet; grade	67.8	990
Brown's Hill siding	69.5	975
Mission creek, water, 960; grade	70.7	966
Mission Creek station	73.4	993
Summit, cutting 18 feet; grade	74.5	1020
Head-stream of Mission creek, water, 1002; grade	75.3	1010
Hinckley	76.6	1032
Grindstone river, water, 1008; grade	77.0	1028
Summit, cutting 11 feet; grade	81.5	1123
Miller	86.3	1136
Creek, water, 1085; grade	90.6	1098
Pine river, water, 1018; grade	93.3	1034
Kettle River station	94.7	1030
Kettle river, water, 1016, grade	95.1	1030
Willow River station	98.8	1038
Willow river, water, 1023; grade	99.1	1033
Sturgeon Lake station (a summit, cutting 5 feet); grade	104.1	1096
Moose river, water, 1041; grade	108.1	1056
Moose Lake station	109.1	1064

St. Croix and Snake rivers.

Determined by the United States engineer corps, under the direction of Capt. C. J. Allen.

	Feet above the sea.
St. Croix river on the east line of Pine county, about	900
At the mouth of Snake river	798
At Rush City ferry	772
Bottom of sluice-gate of Chengwatana dam on the Snake river	929.6
Top of Chengwatana dam	939

This dam flows Cross and Pokegama lakes, and holds the Snake river as nearly level back-water for sixteen miles to Millett's rapids in Kanabec county, even when the gate of the dam is open two or three feet below its top.

The highest portions of Pine county, in its northeastern and northwestern townships, are about 1,200 feet above the sea; and its lowest land, where the St. Croix river crosses its south line, is about 780 feet. The mean elevation of this county is approximately 1,075 feet.

Soil and timber. The subsoil is mostly reddish gray boulder-clay or till, which has a fertile black soil about one foot thick, well adapted for wheat, oats, potatoes, and all the crops that belong to this latitude. Only comparatively small tracts of swamp and of gravelly and sandy modified drift are unsuitable for agriculture. These latter areas are often destitute of timber, or bear only a few small tamaracks in the swamps and scattering red and jack pines on the flat or undulating sandy land.

All other portions of the county are well wooded, bearing white and red pines, spruce, balsam fir, tamarack and arbor-vitæ, the last two named occurring in swamps and along streams; bur, white and black oaks; ironwood; white, red and rock elms; hackberry; black, white and green ash; sugar and soft maples; basswood; wild plum, black cherry, and June-berry; butternut and bitter hickory; yellow and canoe birches; and two species of poplar. Low blueberries, cranberries, red and black raspberries, high blackberry, aromatic wintergreen or checkerberry, black currants, prickly and smooth gooseberries, and hazelnuts, grow in abundance. The huckleberry, mayflower, bearberry and sweet fern were observed at the Lower falls of Kettle river.

GEOLOGICAL STRUCTURE.

Archæan rocks. The most northern outcrops of rock in this county adjoin its north line, occurring near the Kettle river in sections 4 and 9, T. 45, R. 20, and reach thence along a distance of several miles southwesterly, where mica schist, in some portions conspicuously veined with white quartz, is reported as forming knobs 40 to 75 feet high. The continuation of this and associated formations of granite and gneiss toward the southwest is found in Kanabec county at the Upper and Lower falls of Snake river, and in Aitkin county at the dam on this river, situated in the S. W. ¼ of section 21, T. 43, R. 23, a few miles above these falls, and again in the north part of the same township, a few miles above this dam and a half to one mile below the fork of Snake river. Northward, this mica schist continues in Carlton county two miles on the Kettle river, and borders the lower part of Split Rock river, tributary to the Kettle river from the west in section 32, T. 46, R. 20. Six miles farther east a darkish gray hydromica schist, dipping 15° to 25° S. or S. 15° E., outcrops in the vicinity of Moose Lake station, which is two and a half miles north of Pine county line.

Copper-bearing trap. My examination of the trappean rocks and their beds of tufaceous conglomerate, includes the three miles of Kettle river next to its mouth, and also two ledges seen in its west bank about a mile below the mouth of Grindstone river; outcrops on the St. Croix below Kettle river; and a belt crossed by the Snake river in the two miles next east from Chengwatana. Numerous other outcrops of these rocks are reported by Owen and Shumard, and more recently by Irving, on the Kettle river in the ten miles between points examined by me; but through the middle part of this distance, according to Prof. Irving, the river is without exposure of rock for about five miles, mostly in T. 40, R. 20.

In northern Michigan this trappean formation is rich in copper, which is there extensively and profitably mined. Its continuation westward in northern Wisconsin and on the north shore of lake Superior, as also in Pine and Chisago counties, contains generally traces of copper ores, often green in color, most abundant in seams and veins and in decomposing portions of the rock, and rarely particles and even considerable masses of native copper; but no profitable mining of copper has yet been found in Minnesota.

The most northern exposures of trap on the Kettle river are in T. 41, R. 20. The ledges seen by me in this township are situated about twelve rods apart, in the southwest bank, a mile below Grindstone river, being in the S. E. ¼ of section 22. The southern of these outcrops is about seventy-five feet long and rises three to five feet above the river; and the northern has about half this length and hight. Both are trap (diabase), somewhat decomposed, of dull red or dark rusty color, partly amygdaloidal, and much divided by irregular joints and cracks into fragments from one to twelve inches long.

Other outcrops in this township are described as follows by Prof. Irving: "Through sec. 35, T. 41, R. 20 W., the river pursues a nearly southerly course, and on the east side, continuing for over half a mile, is a west-facing cliff 10 to 30 feet high of the typical fine-grained diabase. The east slope of the ledge is gradual, and the strike and dip are plainly to be made out, as respectively N 6° E., and 50° E. On the north line of the same section, and again in section 22, similarly-placed ledges are largely exposed, the river making in this distance about a mile of westing, so that between the south line of T. 41, R. 20 W. and the exposures in section 22 the river crosses a mile in width of Keweenawan beds, with an average eastern dip of 50°. The last place is of great interest, for only 300 paces north of the stream, and directly in the course of the northward-trending diabases, is a cliff of horizontal light-colored Cambrian sandstone 40 feet high and several hundred paces in length."*

Kettle river from the east line of T. 40, R. 20, to its mouth, a distance of about six miles, consists of a succession of rapids, alternating with portions that have a gentle current. My notes cover the lower half of this extent,

* *The Copper-bearing Rocks of Lake Superior* (Monographs of the United States Geological Survey, vol. v), page 244,

beginning at the elbow where the river bends from a south to an east course, in the southern part of section 32, T. 40, R. 19. Prof. Irving's notes on the upper part of these rapids are as follows: "In the N. W. ¼ of the N. E. ¼ of sec. 32, T. 40, R. 19 W., the east bank of the stream shows a diabase ledge 15 feet high and 35 rods long. Just opposite, on the other side of the stream, is a flat-lying reddish conglomerate. Porphyry conglomerate occurs again on the east bank of the river, near the centre of the S. W. ¼ of sec. 29, T. 40, R. 19 W., and again in a large exposure a mile farther up stream in the N. E. ¼ of the S. E. ¼ of sec. 19, where it plainly lies at a very flat angle. These three exposures appear all to be part of the same conglomerate bed. Six hundred paces up stream from the last exposure, typical diabase and diabase-amygdaloid are in sight."

From the bend where my observations begin, an outcrop of trap (diabase) extends about twenty-five rods eastward in the southwest bank of the river, rising perpendicularly at each end about ten feet above the water, but in its middle portion having a hight of only two or three feet. Much of this rock is the usual dark and tough, fine-grained trap; it is minutely pitted upon weathered surfaces; and is often divided by joints into rhombic masses from three inches to two feet long. Some portions are amygdaloidal, holding green bunches of chlorite and prehnite, apparently because of decomposition and metamorphism. Veins of calcite in the form of satin spar, from a sixteenth of an inch to one inch in thickness, and sometimes ten feet or more in length, occur in many of the joints, vertical, oblique and horizontal, in the decomposing parts of these ledges.

About a half mile farther east, near the centre of the S. W. ¼ of the S. W. ¼ of section 33, trap is exposed in the northeast bank of the river, having an extent of a few rods and rising about five feet above low water. This is known as the "copper claim," from prospecting shafts sunk here by Mr. N. C. D. Taylor, in 1865.

Here the river turns south and holds this course to its mouth. A little below the "copper claim," in the north part of the N. W. ¼ of section 4, T. 39, R. 19, its east shore is trap, declining in hight from ten to two feet along its extent of about forty rods from north to south, overlain by a bluff of red till, 25 to 30 feet high.

Next this rock outcrops at many places on the west shore of the river along a distance of nearly a quarter of a mile, at the middle part of the west side of this section 4. It rises one to five feet above the river. Generally it is somewhat decomposed, being often oölitic and nodular, with frequent green stains. Small portions of it are tufaceous conglomerate. It is much divided by joints from two to eighteen inches apart, varying in inclination from 45° to vertical. Their most conspicuous system of parallel planes has an east-northeast strike. All this lower part of Kettle river has low shores or bluffs only 25 to 40 feet high, and the adjoining country is moderately undulating drift.

The mouth of Kettle river is divided by two small islands into three channels. Opposite its mouth and for three miles above and one mile below, the St. Croix river is turned in two channels, by three long islands, which together are called the "Big island." The eastern large channel is the state boundary; and the western is commonly called the "slough." In both the river has a strong current, with numerous rapids, the largest fall being two or three feet in a few rods at a reef of trap which crosses both channels near the middle of the upper island. This extent of about four miles on the St. Croix river is named Kettle River rapids. The highest outcrops of trap in this distance rise only a few feet above the water.

Descending the St. Croix from the mouth of Kettle river, the first rock was found at the south end of the "Big island." Here very compact and hard, fine-grained, dark trap (diabase) has an extent of about twelve rods from east to west and a hight of five feet. Prof. Irving describes this or other neighboring outcrops of the same rock as "apparently striking north and south with a very low eastern dip," and states that light-colored horizontal sandstone is exposed near by.

About a mile farther south, near the south line of section 20, trappean rock, nearly like the last, divided by joints one to four feet apart, forms the west shore of the river for ten or twelve rods, reaching five to ten feet above the water. It again has an exposure of similar extent in the same bank some fifty rods farther southwest, in the N. W. ¼ of section 29, T. 39, R. 19, being about twenty-five rods below the north end of the "Thousand islands," where another ledge of this rock occurs.

The most southern outcrop of trap on this part of the St. Croix is found on the Wisconsin side about a half mile south from the last. Its visible length is only about ten feet, and its hight six feet. Forty rods farther south, opposite the last of the "Thousand islands," is the most northern point on the St. Croix river at which I observed the St. Croix sandstone, which thence is frequently exposed along a distance of nearly twenty miles to the south.

The southwestward continuation of this area of copper-bearing trap is found on the Snake river at Chengwatana and for two miles east. Farther southwest the bed rocks are universally concealed by the drift, as also along this river above to its sandstone outcrops in Kanabec county. Chengwatana dam, in Snake river at the mouth of Cross lake, is built on ledges of trap and conglomerate, which here and in their other outcrops, seen at many places within the next two miles below, rise five to fifteen feet above the river. Their exposures are restricted to its channel and banks, and the adjoining region is gently undulating or nearly level drift, 20 to 50 feet higher. The greater part of this belt consists of dark, hard and compact, fine-grained, tough trap (diabase). Other portions show various stages of decomposition and metamorphism, and bear amygdaloidal masses of chlorite, prehnite, and other minerals, and veins of calcite.

Prof. T. C. Chamberlin has given a detailed description of this locality, and concludes that "the rocks, whether compact diabases, amygdaloids, or conglomerates, are typically Keweenawan in aspect, and leave no room for doubt that they belong to the copper-bearing series and form the western and perhaps terminal margin of the lake Superior synclinal trough."*

Search for copper in these rocks was made several years ago by Mr. Adolph Munch, about three-fourths of a mile below Chengwatana, by several shafts of little depth, upon each side of the river and in its channel. During 1880 and 1881, further prospecting for copper was entered upon by the Chengwatana Mining company, represented by Mr. J. Bennett Smith, who has sunk shafts at three points on the north side of the river, three-fourths of a mile, one mile, and one and a half miles east from Chengwatana. The first of these is in a dark red, ochery conglomerate, which contains many water-worn pebbles, mostly from a half inch to two inches in diameter, apparently derived from the trap, but altered and decomposed. Mr. Smith states that this bed of conglomerate is thirty feet thick, with strike N. 15° E. and dip 70° S. 75° E. He reports another bed of conglomerate, very coarse, fifty feet thick, a half

* *The Copper-bearing Rocks of Lake Superior*, pages 242-3.

mile east of Chengwatana, and a third, about twenty-five feet thick, at the mouth of Cross lake, close above the dam.

At the time of my observation here, October 17, 1881, Mr. Smith was at work at the shaft a mile east of Chengwatana, in an amygdaloidal bed, fifty feet in width, dipping 70° S. 75° E. This had been excavated to a depth of 45 feet, below which farther exploration has since been made with a diamond drill. The hanging wall is very hard, fine-grained black trap; next to this the first five or six feet are soft, decomposed amygdaloid, holding many chloritic bunches, from a quarter of an inch to two inches in diameter; the central and lower portions are somewhat harder, and contain much calcareous spar in crystalline masses and in banded veins, besides a large variety of other minerals; the foot wall is compact and hard, somewhat amygdaloidal trap. All these beds of conglomerate and amygdaloid have approximately the same strike and dip. Professor Chamberlin reports the strike of these strata on the Snake river to be N. 10° to 15° E., and their dip 60° to 70° eastward (S. 75° to 80° E.). The formation was made up by successive overflows of molten rock, which cooled to form hard finely crystalline trap (diabase) beneath, but often in the upper part became scoriaceous and amygdaloidal; and between these eruptions, during intervals of repose, layers of tufaceous conglomerate sometimes were accumulated.

St. Croix sandstone. An area of sandstone, referred to the lower part of the St. Croix formation,* extends on the Kettle river from about three miles north of Kettle River station southward along a distance of twenty or twenty-five miles. The most northern outcrop of this sandstone is reported in a bluff at the west side of Kettle river near the southwest corner of section 10, T. 44, R. 20. Its next exposure is one and a half miles south of Kettle River station, in the north part of section 3, T. 43, R. 20, where it rises about ten feet in the northeast bank of Kettle river. Here and frequently onward to the mouth of the Grindstone river, this rock forms the river-bed and produces rapids. Where the old Government road crossed the Kettle river, one and a half miles below this reef, the sandstone rises ten to fifteen feet in its right bank. Through the next fifteen miles, to about a mile below the Grindstone river, a deep channel has been eroded by the Kettle river in this formation,

* This sandstone is not a legitimate part of the St. Croix formation, but is separated from it by a bed of shales from seventy-five to a hundred feet thick. It may represent the Potsdam sandstone. Compare the report on Goodhue county, p. 32.—N. H. W.

which is seen almost uninterruptedly along both sides, often making a wall 5 to 20 feet high at the water's edge, and ascending within a distance of an eighth to a third of a mile from the stream in bluffs 75 to 100 feet high, their upper half being usually vertical cliffs. Occasionally tower-like masses are left isolated beyond the line of the bluff, the edge of which, also, is in many places broken into immense blocks, some of which have been already dislodged, while others are separated by yawning chasms, from one to six feet or more across and ten to twenty-five feet deep, ending in cavernous clefts and recesses below. This whole gorge fifteen miles long, like that of the Mississippi eight miles long from Fort Snelling to Minneapolis, has probably been cut by the river since the ice age. The drift in the vicinity of this part of Kettle river is thin, and the sandstone reaches from the base to the top of its bluffs, which rise to the general level of the adjoining country, 75 to 100 feet higher than the surface at Kettle River station. On tributary ravines and creeks this rock often forms picturesque cliffs to a distance of a half mile or one mile above their mouths; but farther back the water-courses are usually of small depth, not cutting through the moderately undulating drift-sheet, and only few exposures of the underlying sandstone are known. This sandstone is mostly fine but partly coarse in grain, rarely conglomeritic, seldom very hard and sometimes easily crumbling, usually gray or buff in color, and in stratification nearly level or inclined only a few degrees.

At the Upper falls (or Dalles) of the Kettle river, situated four miles east of Miller station, in the south edge of T. 43, R. 20, the river flows southwest in rapids about a half mile long, closely bordered upon each side by ragged cliffs of this rock 50 to 100 feet high. About a sixth of a mile below the foot of this rapid, a little stream joins the river from the west, having a pretty water-fall, 13 feet high, a dozen rods above its mouth. Here the sandstone rises in successive steps of ten to twenty feet each, often overhanging, to a hight about 75 feet above the river. It is fine-grained, slightly reddish or yellowish brown, and bedded in layers from six inches to three feet thick. These layers are nearly level, but resemble many modern sand deposits in being often obliquely laminated, their dips varying from 10° to 45°, mostly southward. On the small tributary mentioned, this sandstone forms a picturesque ravine extending about a mile northwestward from the river. At a basin near the head of this gorge, it dips about three feet in a hundred feet, or approximately two degrees, to the southeast.

The Lower falls of Kettle river are in the south part of section 15, T. 42, R. 20, being a short distance below a very large chalybeate spring which issues at the foot of the eastern bluff, and about a mile south of a tributary whose loudly dashing descent down this bluff is hidden from view by heavy woods. In the three miles between these falls of Kettle river, it flows with a gentle current. At the Lower falls the sandstone forms both shores and the river's channel, in the middle of which it rises in an island with vertical walls and nearly level top, about a hundred feet across, and 10 or 12 feet above the water at the head of this fall. West of the island is a perpendicular descent of four or five feet, with rapids which fall two feet within a few rods above, and as much more within twenty rods below, making a total of about eight feet. East and south of the island the descent is a nearly continuous rapid, broken by vertical falls of only about one foot. The sandstone here is fine-grained and somewhat friable; its color is yellowish gray; and its stratification, in beds from six inches to three feet thick, has a slight dip to the south, varying from one to four feet in a hundred feet.

In sections 16 and 17 of this township, one and two miles west from the Lower falls, exposures of this sandstone occur on the south side of a small brook, 10 to 20 feet above it, and at the general level of the surrounding drift-covered country. In the west part of section 17, it is hard and fine-grained, and was quarried several years ago to test its value as a grindstone.

At Hinckley, on the Grindstone river four miles above its mouth, this sandstone has been quarried by the Saint Paul & Duluth railroad company. The section thus exposed is six to nine feet high and about 250 feet long from north to south, lying close north of the river and east of the railroad. The top of this ledge is twelve feet above the river, and is overlain by three to eight feet of very coarse gravel, nearly like till. This rock is a hard and compact, medium-grained sandstone of light buff color, nearly level in stratification. Its beds vary from one inch to two feet in thickness, and in some portions they show oblique lamination, which is inclined 10° to 15° northward. Quarrying was begun here in 1878, since which time this stone has been largely used for bridge-masonry.

This rock is reported to occur frequently in large blocks, and perhaps has low outcrops in place, along the north branch of Grindstone river, and about Grindstone lake. Below Hinckley this river has cut its channel about fifty feet deep in drift deposits, and no exposures of rock in place were found. From its mouth north along Kettle river, the sandstone occurs in the bluffs, has extensive exposures where the old Government road crosses Deer creek, and forms Pine Island rapids about four miles south of the Lower falls. A half mile to one mile below the mouth of Grindstone river, ledges of sandstone, nearly level in bedding, light gray in color, and often containing fine gravel up to an eighth or a fourth of an inch in diameter, occur a short distance west of Kettle river, having a hight 20 to 40 feet above it. On the east side of Kettle river here and probably at intervals through several miles farther southeast, to the head of the rapids and abundant trappean outcrops which reach thence to its mouth, an interrupted line of sandstone bluffs, declining southeastward from 50 to 25 feet in hight, is found a fourth to a third of a mile from the river.

The next observation of sandstone southeastward is by Owen, who reports it on the southeast side of the St. Croix river a little below the head of the Kettle River rapids. It is red, much shattered, and is underlain by a conglomerate. Near by are numerous outcrops of cupriferous eruptive rock.*

Below the Chengwatana trappean belt, the next exposures of rock on the Snake river are near its mouth. Its northeast bluff in the S. ½ of the N. E. ¼ of section 36, T. 39, R. 20, about a mile above its junction with the St. Croix, has an outcrop of gray and white sandstone, which extends about twenty rods, rising ten to fifteen feet above the river. This is a levelly stratified, somewhat friable rock, in layers from three inches to one and a half feet thick, mostly intersected by nearly vertical joints two to five feet apart. It was quarried a few years ago by Mr. T. R. Rice and others for the foundation of the court house at Grantsburgh, seven miles east in Burnett county, Wisconsin. Two or three feet above the line of low water, this sandstone includes a layer of conglomerate, one foot thick, composed of gravel and pebbles up to an inch in diameter, mostly white quartz, all much water-worn.

Half a mile farther east, where the river turns from a north to an east

* East and northeast from the Kettle River rapids on the St. Croix, no outcrops of the bed-rock have been learned of in Pine county, by much inquiry addressed to surveyors and lumbermen who are familiar with this part of the St. Croix and with its tributaries, Bear, Sand, Crooked and Tamarack creeks. The region consists chiefly of till, rising by gentle slopes to hights 25 to 50 feet above the streams, and is well timbered with hard wood and much red and white pine,

course, about a hundred rods above its mouth, another outcrop of this formation was seen along an extent of about fifty feet and to a hight of six feet. The lowest beds here, about four feet in hight, are whitish and yellowish, somewhat pebbly sandstone, in layers from a quarter of an inch to six inches thick; in part rhomboidally divided by many joints; levelly stratified at the east, but at the middle of the exposure dipping 1° to 10° southwesterly and disappearing. The overlying beds are soft, finely laminated shales, red, green and yellow. Their red layers are from an inch to one and a half feet thick, rarely enclosing yellow laminæ; and the green vary from one to four inches in thickness, including yellow layers up to three-fourths of an inch thick.

On the St. Croix river similar beds were noted in its southeast bank, opposite the most southern of the "Thousand islands," a mile above the mouth of Snake river. Here whitish and slightly yellowish, soft sandstone was exposed along a distance of forty feet, and to a hight of ten feet above the water, in the base of a high bluff. It is bedded in horizontal layers, which are obliquely laminated, and vary from three to twelve inches in thickness, sometimes divided by layers a quarter of an inch to one inch thick of greenish sand. Under this sandstone, the three feet next to the water consisted of soft shales, the upper one and a half to two feet being dark red, finely laminated, with occasional thin streaks of green or yellow; then, about a foot of light green color, with little yellow and red, underlain at the water's edge by a second red stratum. An eighth of a mile farther south this eastern bluff, about 90 feet high, exposes a vertical thickness of fifteen feet of nearly white, level sandstone, 35 to 50 feet above the river.

A quarter of a mile below the mouth of Snake river, this sandstone occurs, thinly covered with alluvium, a few rods north of Mr. T. R. Rice's house, on the Wisconsin side, being eight or ten feet above the St. Croix.

The Horse-race rapids, not broken by boulders, are a half mile long, lying mostly in the N. E. ¼ of section 7, T. 38, R. 19. The next half mile of the St. Croix, two to two and a half miles below Snake river, is bordered on the Wisconsin side by perpendicular cliffs of white, coarse-grained, soft and crumbling, horizontally bedded sandstone, about 50 feet high.

These beds of sandstone and shales occurring on the St. Croix river south from the Kettle River rapids, and on the Snake river near its mouth, are probably the middle part of the St. Croix formation or group, being higher stratigraphically than the beds seen on the Kettle river.

Glacial and modified drift. Glacial striæ, seen at several places on the sandstone at Hinckley, ran S. and S. 5° W., by the true meridian.

The average thickness of the drift deposits on this county is estimated to be about seventy-five feet. In some parts it is comparatively thin, but in other parts it exceeds one hundred feet. Except near the southern border, both the till and modified drift have a distinctly reddish tint, being colored thus by the part of their material derived from red sandstone and shales in the region of lake Superior. The plentiful boulders of the till include granite, syenite, gneiss and crystalline schists, reddish felsitic rock of igneous or metamorphic origin, dark and very hard trap, black slaty rocks, red sandstone, and rarely fragments of conglomerate.

South of the Snake river, however, in the morainic hills of Royalton and northeast to Devil's lake and the south end of Cross lake, as also on the flat area of till extending thence eastward, the felsitic, trappean, slaty and conglomerate boulders, which are referable to the region on the northeast, are less frequent or absent; and the color of the drift is dark bluish at a considerable depth, weathered to yellowish gray near the surface, instead of the reddish tint observed farther north. Limestone boulders and gravel, brought by an ice-current from the west, are also found in these deposits of till south of the Snake river, but none occur elsewhere in this county.

The morainic accumulations and the flat or slightly undulating till thus shown to be brought from the west probably were deposited at the time of the fifth or Elysian moraine. At this time and while the later sixth, seventh and eighth (or Waconia, Dovre and Fergus Falls) moraines were being formed, the southern boundary of the lake Superior lobe of the ice-sheet probably crossed this county, the Fergus Falls moraine being perhaps represented by the drift hills that border the Pine lakes and extend northeastward nearly to Kettle River station. The continuation of this moraine should be looked for from Sturgeon lake eastward in the northern tier of townships.

An old glacial outlet of lake Superior. During the time of formation of the Fergus Falls and Leaf Hills moraines, the west part of the basin of lake Superior, vacated by the retreating ice-sheet, held a lake at a level about five hundred feet above the present surface of lake Superior, because ice still filled the north and east parts of this lake basin. The outlet of the lake at this stage is found at the head of the Bois Brulé river in northwestern Wisconsin. Mr. H. S. Treherne describes the source of this stream as a swamp extending several miles in a valley which is eroded 75 to 100 feet below the adjoining country, the distance between its bluffs in the narrowest place being about 1,000 feet. The highest part of the swamp at the divide between the Bois Brulé and St. Croix rivers is 1,070 feet above the sea. Along this avenue the outflow from lake Superior while thus pent up by the ice-barrier on the east passed south to the St. Croix river. When it began to cut a channel for itself, the highest land that it flowed over was about 1,150 feet above the sea, or 550 feet above lake Superior. Probably the highest part of the swamp has been filled twenty or twenty-five feet since the lake forsook this mouth, which was thus lowered by erosion to 450 feet, approximately, above the present lake-level. The Upper St. Croix lake, 1,011 feet above the sea, about four miles long and a half mile wide, is formed like Big Stone lake, Lac qui Parle and lake Pepin, the old valley, in which the lake lies, having been filled below it by the alluvium of its tributaries.

The gravel and sand of the modified drift, thinly spread with a flat or slightly undulating surface upon the till in the vicinity of Pine City and along the Snake, Kettle and St. Croix rivers, and accumulated more or less in swells and kame-like knolls and short ridges, 10 to 30 feet high, along a distance of several miles south and north of Kettle River station, were deposited during the recession of the ice-sheet, these sediments from the glacial rivers having been contained, together with boulders and clay, in the lower part of the ice, being finally exposed on its surface as it melted. The knolly and ridged contour of some of these deposits is due to their being laid down by the glacial streams before they had passed the ice-margin, in basins and channels of ice, which afterward melted away.

Copper nuggets. A mass of drift copper weighing eighty pounds is said to have been found by Scott La Prairie in the bed of the Snake river a short distance below Chengwatana. Another piece weighing twenty-two pounds was found on the St. Croix river about three miles east of the mouth of Tamarack creek. Other pieces from a few ounces or less to a few pounds in weight have been frequently found in the drift or on the surface, especially in the gravelly beds of streams.

Wells in Pine county.

Kettle River. The well of the railroad water-tank at Kettle River station is 10 feet deep, all red gravel and sand; soft water.

At Pine River mills, one and a half miles southwest from the station, wells go in the same modified drift 8 to 13 feet.

Hinckley. The railroad well, 25 feet deep is soil and clay, 2 feet, succeeded below by sand and gravel to the bottom. Other wells in this village have the same section, but are mostly only 15 to 20 feet deep. Some of these wells have soft water, nearly as good to wash with as rain-water; but in others the water is somewhat hard, not being quite satisfactory for use in washing with soap.

Pine City. Wells in the town are 10 to 20 feet deep, all sand and fine gravel; water plentiful and of excellent quality, but somewhat hard, as also are all the wells and springs in this county south of the Snake river.

A well at the old stave-factory close south of the town, is 30 feet deep, all the way in yellow till, to water in gravel and sand at the bottom.

J. D. Wilcox; S. E. ¼ of sec. 33, a half mile southeast from Pine City: well dug 24 feet and bored 29 feet lower; yellow till, hard, picked, 20; dark bluish till, moist and softer, containing little gravel, like the till of southern and western Minnesota, 33; the only water obtained was at the base of the yellow till, not rising but filling the reservoir dug four feet below in the blue till.

Royalton. D. Peterson; N. W. ¼ of sec. 15: well, 26 feet; yellow till, 6; dark bluish till, harder than the yellow, requiring to be picked, 13; and sand, 6 feet and continuing lower.

MATERIAL RESOURCES.

The agricultural capabilities of Pine county, and its valuable forests, have been noted in an earlier part of this chapter. Much lumber is manufactured here, but mostly by steam-mills; and a far greater amount, cut from the pineries of this county and on the upper waters of the St. Croix and Snake rivers, is floated down the St. Croix to be manufactured at Stillwater and points farther south.

Water-powers are available on nearly all the streams, and with the more full settlement of this region they will doubtless be utilized for the manufacture of lumber, furniture and wooden wares, and for flouring mills. The only water-power employed for manufacturing in 1881 was at the Pine River mill, in section 32 of the west part of Kettle River, owned by Wyman X. Folsom, sawing lumber and making shingles, having about eight feet head.

Dams built to provide water for log-driving are as follows:

On the Snake river at Chengwatana, having a head of nine or ten feet, ponding the river back through Cross and Pokegama lakes and onward to a point about four miles west of the county line. From the Chengwatana dam to its mouth the Snake river descends by a gradual slope 130 feet in about nine miles, averaging fourteen feet per mile.

On the Grindstone river are five dams, one at the mouth of Grindstone lake, which is raised by it six feet; a second in the S. E. ¼ of section 10, Hinckley, nearly three miles northwest from the station, having a head of twelve feet; a third at Brinnan & Strong's steam saw-mill in Hinckley village west of the railroad, having a head of ten feet, used for floating logs to the mill but not for water-power; a fourth, situated one mile east of Hinckley, having about six feet head; and the fifth and lowest, at the old Government road crossing, a mile above the mouth of the river, having seven or eight feet head.

Kettle river has no dams, but some of the tributaries of the St. Croix in this county farther east, on which much lumbering is done, have such dams for log-driving.

The St. Croix river has a strong current along the boundary of Pine county, its descent being about 120 feet, or an average of nearly three feet per mile.

Building stone. A quarry of hard and durable light-buff sandstone is worked at Hinckley. It has been more fully described in the preceding pages. Probably rock of nearly the same quality might be quarried on section 17, T. 42, R. 20, two and a half miles southeast from Miller. The trap-rocks at Chengwatana and the white sandstone on the Snake river near its mouth, though less valuable stone, have been also quarried for building purposes.*

Springs. On many of the streams, and occasionally on the borders of lakes, springs of very clear, cold water are found. In many cases the presence of iron in the water is shown by iron-rust deposited on the sides and bottom of the spring. The most noteworthy is the Big spring, situated on the east side of the Kettle river, three or four rods from it and some five feet above it, about an eighth of a mile north of the Lower falls. It issues at the foot of a nearly perpendicular sandstone wall, and fills a basin about three rods across and three to five feet deep with very transparent water. A considerable stream is constantly flowing from it.

ABORIGINAL EARTHWORKS.

Several artificial mounds of the usual round form, varying from one and a half to three feet in hight, were observed along a distance of some twenty-five rods close east to the road from Pine City to Chengwatana about a mile north from the south end of Cross lake and an eighth of a mile north from a school-house, on land some fifteen feet above the lake and six to twelve rods east from its shore.

At Pine City a mound about twelve feet high was leveled down on the land used for the lumber-yard of the steam saw-mill. It was some twenty rods south of Snake river and a quarter of a mile west from Cross lake, on land ten or fifteen feet above the river. Captain Sod, a Chippewa about a hundred years old, says that after a battle with the Sioux (Dakotas), some of them were buried in this mound, one being a very large man. This was an intrusive burial, the mound having been built at some much earlier date. In its removal, several skeletons were exhumed, some being found in erect position, and one was of gigantic size. No other mounds were learned of in this vicinity.

On an island in Pokegama lake an aboriginal earthwork about six feet high, possibly designed for military defense, is now flowed around by water raised by the Chengwatana dam. A musket and a skull are said to have been dug from this mound.

* Since this report was written by Mr. Upham an important quarrying industry has sprung up on the Kettle river, giving rise to a village known as Sandstone, situated a short distance south from where the old government road crosses the Kettle river, northeast from Miller. Here the bluffs of sandrock rise about 100 feet, sometimes nearly vertical from the water, but more frequently at some distance back from the river, the intervening area being occupied by a coarse talus of screes that descends from the top to the water level. The gorge is old, and was once probably a course of drainage for an outlet of lake Superior at a date somewhat earlier than that described by Mr. Upham by way of the St. Croix lake. The last drift epoch probably found this gorge in existence, and it was occupied with glacial waters during its prevalence. The scantiness of the drift-sheet, as described by Mr. Upham, indicates this no less than the width and depth of the gorge itself. There is an inexhaustible amount of a fine building-stone in these bluffs. This rock is shipped extensively to Minneapolis, and somewhat to St. Paul and Duluth. It is light-colored, and is described as *Hinckley sandrock* in vol. i. of this report. The chief opening is owned by Grant and Knowles, St. Paul, and leased by King and Tobin, Minneapolis. The rounded grains of pure quartz are sufficiently cemented by interstitial silica to render them angular when disintegrated, and to produce a very durable, and sometimes a very hard siliceous rock which in some parts is a true quartzyte. During the season of 1887 one hundred and twenty men were continually occupied at this quarry, and an average of six cars per day, each containing about 35,000 pounds, were shipped away. It sells for 35 cents per cubic foot, or 35 cents per face foot when dressed. The new Science Hall, of the University of Minnesota is built largely of this stone.—N. H. W.

CHAPTER XXIX.

THE GEOLOGY OF BECKER COUNTY.

BY WARREN UPHAM.

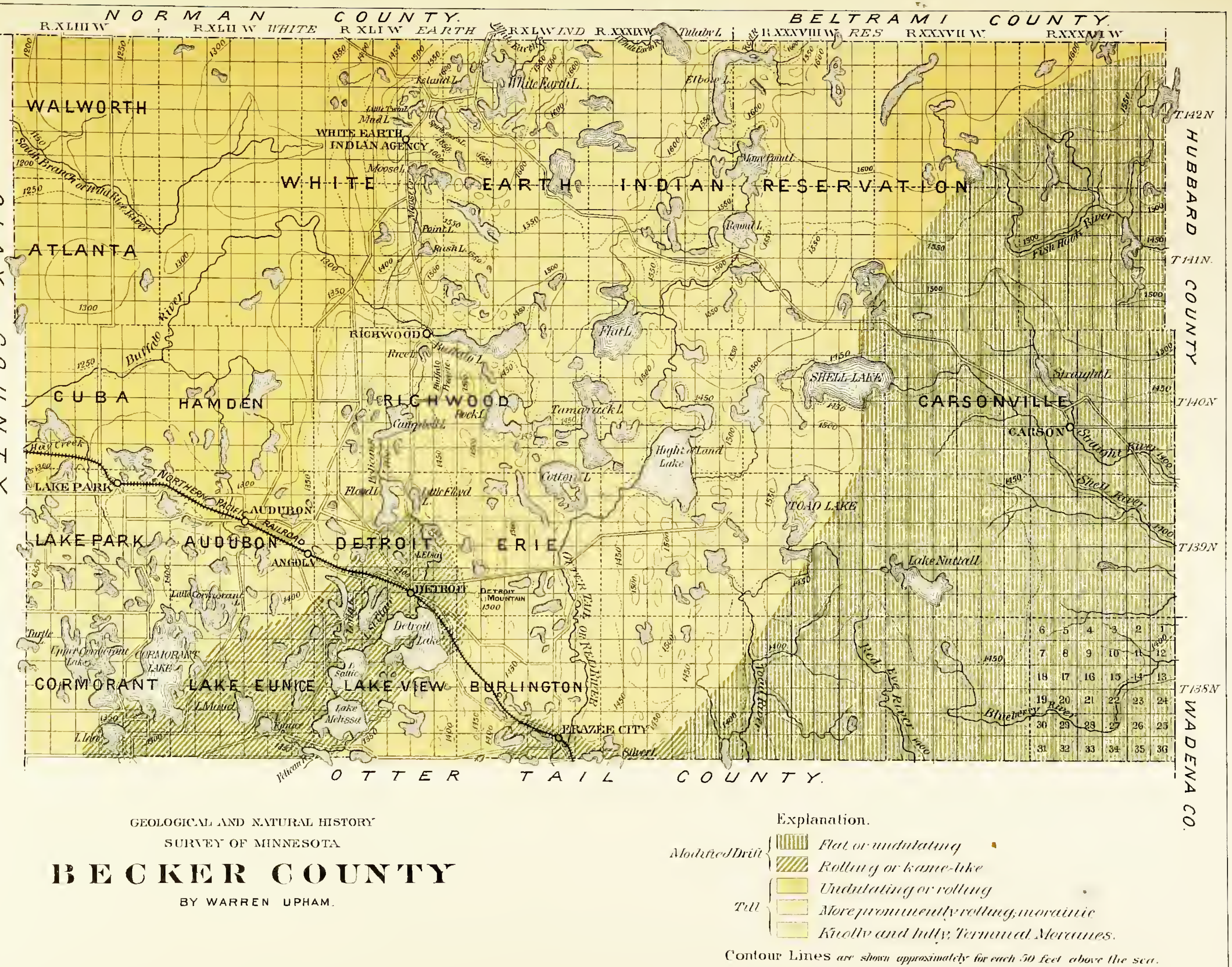
Situation and area. Becker county (plate 60) lies in northwestern Minnesota. Itasca lake, the source of the Mississippi, is only three miles north of the northeast corner of this county. Detroit, the county seat and largest town, is about a hundred and eighty miles northwest from Minneapolis and Saint Paul. Frazee City, Audubon and Lake Park are also prosperous villages.

The length of Becker county from east to west is forty-eight miles, and its width is thirty miles, including forty townships of the governmental surveys. More exactly stated, its area is 1,445.41 square miles, or 925,060.75 acres, of which 88,073.66 acres are covered by water.

SURFACE FEATURES.

Natural drainage. About three-fourths of this county lies within the basin of the Red river of the North. The source of Otter Tail river, the head-stream of the Red river, is a few miles north of the north line of Becker county, being thirteen miles west of Itasca lake. Thence the Otter Tail river flows south through this county, and in Otter Tail and Wilkin counties, taking the name Red river, it turns its course to the west and north. Toad and Pelican rivers are affluents of this main stream, with which they unite in Otter Tail county. The northwest part of Becker county is drained by the head-streams of the Buffalo and Wild Rice rivers, which flow westward to the Red river.

On the east are the sources of the Fish Hook, Straight, Shell, Blueberry



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

BECKER COUNTY

BY WARREN UPHAM.

LITH. PIONEER PRESS CO. ST. PAUL.

and Red Eye rivers, which drain the two most eastern ranges of townships and portions of the one next farther west, flowing eastward into the Crow Wing river and so to the Mississippi.

Lakes. This county is well supplied with lakes, the largest being Cormorant lake, about five miles long and two miles wide, in its southwest corner, emptying southward to Pelican lake and river in Otter Tail county. Closely associated with this are Upper Cormorant and Little Cormorant lakes and lake Ida. The Pelican river flows through lake Gabriel, Floyd and Detroit lakes, and lakes Sallie and Melissa, besides several others of larger size in Otter Tail county. Lakes Maud and Eunice, the latter giving its name to a township, are tributary to this river near the south line of the county. Buffalo, Flat and Rock lakes are the head of Buffalo river; and White Earth river, a branch of the Wild Rice, begins in Tulaby and White Earth lakes. The Otter Tail river in this county flows through Elbow, Many Point, Round, Hight of Land, and several other lakes. In the east part of the county, Toad, Shell and Straight lakes are at or near the sources of the rivers so named. The map shows about a hundred lakes that equal or exceed a half mile in length.

Topography. The surface varies in contour from slightly undulating, with swells 5 to 15 or 20 feet above the depressions, lakes and streams, to massively rolling in swells 30 to 50 feet high, with long, smooth slopes, and roughly knolly and hilly, with elevations 25 to 75 feet above the irregular enclosed hollows, sloughs and lakelets. The last described type of contour marks the belts of morainic drift, one of which, three to five miles wide, extends from White Earth lake and Agency southward through Richwood and the western two-thirds of Erie and Burlington. Another belt of similarly hilly drift lies nearly parallel with this a few miles farther east.

From the south part of the county a very gradual ascent rises about two hundred feet in crossing it northward upon its eastern two-thirds, to a western limit at the White Earth Agency, the elevation of these northern townships being about 1,600 feet above the sea. At the Agency a very beautiful view is seen westward, overlooking the half dozen northwestern townships and portions of Clay and Norman counties beyond. In the first four miles west from the White Earth Agency there is a descent of about three hundred feet, and from its base the smoothly undulating northwestern townships, 1,300 to 1,150 feet above the sea, descend with a very gentle slope to the west and northwest. The lowest part of this area is in Walworth and northwestern Atlanta. The west boundary of the county farther south is 1,300 feet, within fifty feet more or less, above sea-level.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, Saint Paul.

	Miles from Duluth.	Feet above the sea.
Otter Tail river, bed, 1358; grade - - -	196.2	1385
Frazee City - - -	196.8	1389

	Miles from Duluth.	Feet above the sea.
Summit, natural ground	201.4	1422
Johnson	201.7	1394
Depression at Detroit lake, grade	204.7	1347
Pelican river, bed, 1339; grade	205.8	1352
Detroit	206.6	1364
Summit, cutting 7 feet; grade	208.6	1390
Cut 31 feet deep, grade	210.7	1377
Audubon	213.6	1310
Creek, bed, 1270; grade	214.7	1295
Summit, natural ground	217.0	1350
Lake Park	219.2	1336
Hay creek, bed, 1253; grade	221.0	1286

The extremes of elevation in Becker county are about 1,600 to 1,650 feet in its northern part, and about 1,150 feet where the South branch of the Wild Rice river crosses its west line. Estimated hights of some of the larger lakes are as follows: Detroit lake, 1,335 feet; lakes Sallie and Melissa, 1,330; Pelican lake (in Otter Tail county), 1,320; Cormorant lake, 1,350; Hight of Land and Shell lakes, 1,425; White Earth lake, 1,500. The mean elevation of Becker county, estimated according to the contour lines of the map, is approximately 1,440 feet above the sea.

Soil and timber. This county has a fertile soil, and is fast being brought under cultivation. The only tracts not suited for agriculture are the bluffs of streams, frequent marshes or sloughs which yield a valuable crop of hay, and certain roughly knolly or hilly and stony portions of the morainic belts, which will yet have utility for their timber or as pastures when cleared.

The eastern two-thirds of the county are in part lightly and in part heavily timbered, but also include occasional tracts of "brush prairie," which has few or no trees but bears shrubs, as dwarfed oaks, hazel, prairie willow, bearberry, wolfberry, New Jersey tea, and the lead plant, commonly called "shoestrings" in allusion to its long and slender, tough roots, which are troublesome in plowing. The Second prairie of Straight river, which is mostly of this kind but is partly natural grassland, without bushes, extends from Hubbard county westward along the north side of Straight river in Carsonville nearly to Carson City; and the Third prairie, somewhat brushy throughout its whole extent, lying between the Straight and Shell rivers, stretches from Carson City four miles to the west and about seven miles to the north. The woodlands of this eastern third of the county are mostly rather open and the ground grassy, so that they afford good pasturage.

Prairie extends from the Red river valley eastward to the White Earth Agency and Detroit, occupying the western third of the county. The south half of this third, however, has frequent groves, both on lake-shores and on the rolling uplands, giving a very pretty, park-like aspect to many portions of Detroit, Audubon, Lake Park, Cormorant, Lake Eunice and Lake View.

The following species of trees and shrubs have been observed in Becker and Otter Tail counties, by Mr. R. L. Frazee, manufacturer of lumber at Frazee City: white pine, red (often called "Norway") pine, and gray or Banks' pine, commonly called "jack pine," black spruce, balsam fir, balsam poplar, paper or canoe birch, and beaked hazelnut, common northeast from the Northern Pacific railroad; white elm, bass, sugar maple, box-elder, black ash, bur and white oak, ironwood, species of willow, poplar or aspen, tamarack, prickly ash, smooth sumach, climbing bitter-sweet, wild plum, wild red cherry and choke cherry, nine-bark, red raspberry and high blackberry, thorn, June-berry, prickly and smooth gooseberries, black currant, wolfberry, high bush cranberry, and hazelnut (Corylus Americana), common generally; slippery or red elm, black oak, large-toothed poplar, and black cherry, less frequent; red oak, silver and red maples, black raspberries, and elder, scarce; cottonwood, seen rarely about the shores of lakes; and hackberry, known only at one place, which is in Otter Tail county near lake Lida.

Several species of trees and shrubs not in this list were identified by Mr. O. E. Garrison between the White Earth Agency and the Otter Tail river on the road to Carson City, namely, white, red and green ash, swamp white-oak, gray oak, water beech, white spruce, moose-wood, sheep-berry, arrow-wood, yellow honeysuckle, bush-honeysuckle, hoary alder, low birch, sand cherry, meadow-sweet, hardhack, and wild rose.

Arbor-vitæ and mountain ash occur in the vicinity of Straight and Shell lakes, this being their southwestern limit. Low blueberries, bog cranberries, strawberries, and Seneca snake-root, are plentiful. Large quantities of the latter are gathered and sold by the Chippewa Indians. Besides the pines and other conifers, many species of shrubs, herbaceous flowering plants, ferns and mosses, grow in this northern forest to southwestern limits here approximately coincident with the line of the Northern Pacific railroad.

GEOLOGICAL STRUCTURE.

No exposure of the bed-rock is known in Becker county, but blocks of very hard, light buff magnesian limestone, up to ten or twelve feet in length, occur abundantly on the descending slope west of the White Earth Agency, especially in ravines about three miles from the Agency, some two hundred feet below that place and a hundred feet above the slightly undulating plain on the west. Limestone boulders are also very plentiful and large in some places on the rolling land one to two miles south of Audubon, 75 to 100 feet above that station, having thus approximately the same hight of 1,400 feet above the sea, as in the ravines mentioned west of the White Earth Agency. The distance between these localities is about twenty miles in a line from north to south. They are in the course of a prominent terrace-like belt of ascending slope which extends from west to east along the south side of the railroad through Audubon and thence bends to the north, extending along the east side of Audubon and Hamden and onward in range 41 to the north line of the county. In Audubon, Detroit and Richwood, it rises about a hundred feet in one or two miles, and northward its ascent increases to three hundred feet, which change in level is made upon a rolling belt about four miles wide. Beyond the limits of Becker county this belt continues northward and northeastward, and is a very prominent topographic feature for a distance of at least sixty miles, to the region between Red lake and the head of the Turtle river; while on the southwest it is continued, with nearly the same character as in Audubon, through Lake Park and thence west and south in Clay county through Eglund, Parke and Tansem, and through the entire extent of the most western range of townships of Otter Tail county, the ascent along this distance of fifty miles from north to south being a hundred to a hundred and fifty feet within a width of two or three miles.

This line of terrace-like ascent is thus a very remarkable and conspicuous feature in the contour of this region for more than a hundred miles. On one side of it an undulating and rolling plateau-like area stretches far to the east, maintaining nearly the same average elevation as the top of this slope, which increases in hight northward from 1,400 feet in Otter Tail county to 1,600 feet about the sources of the Otter Tail and Mississippi rivers. On the other side a smoothly undulating or flat surface descends by a very gentle slope to the Red river. Drift deposits universally conceal the bed-rock upon all this region, but the great abundance of limestone boulders at the localities before described, this great terrace a hundred miles long, and the section of a well drilled at Humboldt, six miles southeast of Saint Vincent, through 295 feet (from the depth of 180 to 475 feet) of such light-buff magnesian limestone, believed to be of the same age as the Lower Magnesian limestone in the Minnesota and Mississippi valleys, together make it highly probable that the same formation, existing in the form of an escarpment under the drift, is the cause of this terrace.

Outcrops of the rocks of the Trenton formation near Winnipeg show that the dip of this limestone must be toward the northwest. The continuation of the latter, to which most of the limestone blocks and boulders observed in this county doubtless belong, would probably coincide in elevation with this terrace, which seems therefore to be due to the erosion of the limestone for some distance thence westward and northward, although it remains at Humboldt a hundred miles farther northwest, where it lies at a much lower level and was not removed in the process of denudation that formed the broad Red River valley. Somewhere within probably fifty to a hundred miles east of the terrace, this limestone would abut upon the edge of the Archæan granites, syenites and schists of central and northern Minnesota, with the intervention of the Potsdam red sandstone or quartzyte in some places, as observed at Pokegama falls on the upper Mississippi river and at the falls on Prairie river four miles farther northeast.

Patches of Cretaceous deposits doubtless underlie the drift here and there, separating it by probably a comparatively small thickness of shales from the floor of Cambrian or Archæan rocks.

Glacial and modified drift. The average thickness of the drift in this county is probably about a hundred and fifty feet. Its base is not reached by the deepest wells, excepting at two places in Audubon. Its topographic expression and differences of elevation have been stated on preceding pages. The greater part of the two morainic belts is boulder-clay or till, often with very plentiful boulders. Till also forms the intervening tract, and is spread with a smoothly undulating or rolling surface over the western portion of the county, excepting a considerable area of prominently rolling modified drift, which extends from the north part of Detroit southwesterly to Pelican Rapids in Otter Tail county. In the report of that county an attempt to explain the mode of deposition of these swells and smoothly sloping massive hills of stratified gravel and sand has been already given. The total length of this area is about thirty miles, and its width is from three to eight miles. The slopes of these swells and hills vary in steepness from one to ten feet in a hundred. In Detroit and the northwest part of Lake View they rise 30 to 40 feet above the intervening depressions, sloughs and lakelets; in Lake Eunice township their hight is 40 to 75 feet; and in the southeast part of Cormorant they are 75 to 100 feet high, charmingly grouped, presenting in the combination of lakes, groves, and broadly massive, smooth hills, clad with the prairie greensward, a very pleasing prospect. The highest part of the road in section 35, Cormorant, is a good point from which to take in this view.

Gravel and sand of the modified drift also occur in considerable amount, with the till, as a component of the morainic belts, occasionally forming the crests of the highest knobs, as of "Detroit mountain," which lies three miles east of Detroit, rising about 125 feet above the adjoining country at its west side, or approximately 1,500 feet above the sea. On the smooth sheet of till farther west deposits of kame-like gravel and sand were observed rarely, forming knolls 15 or 20 feet above the surrounding expanse. In the east part of the county gravel and sand were spread quite widely by the glacial floods in a rather thin sheet upon the till, the thickness of the modified drift being usually 10 to 30 feet. Though the subsoil there and around Detroit and thence southwestward to Cormorant and Pelican lakes is gravel and sand, it is covered by a fertile black soil and is good farming land, owing partly to the presence of much fine detritus of limestone.

Besides the limestone boulders of the till, it has many of granite, syenite and schist; indeed, the latter kinds predominate, being generally nine-tenths or nineteen-twentieths of all. In the west and especially the northwest part of this county, the proportion of boulders is small, a larger part of the till there being derived from Cretaceous shales, its transportation by the ice-sheet having been from northwest to southeast. In the east half of the county the diminishing proportion of limestone and the more abundant granitic boulders indicate that the glacial currents there came mainly from the north and northeast.

The two series of morainic drift knolls and hills that extend from north to south through the central part of this county, were accumulated on the west border of the receding ice-sheet and belong to the time of the eighth and ninth or Fergus Falls and Leaf Hills moraines. The tenth or Itasca moraine, next on the north and east, touches the northeast corner of Becker county. At the time of its formation all the remainder of this county was uncovered from the ice-sheet.

A bed of shell-marl occurs in the banks of Buffalo river in section 28, T. 141, R. 41, seven miles south of the White Earth Agency. The stream is in a valley 30 to 40 feet below the adjoining country. Its banks about twenty rods southeast from the bridge are made up of soil, 2 feet; white, shelly marl, 1 foot; and alluvial sand and gravel, 6 feet, to the level of the water. Probably the names of White Earth river and lake, and of the Indian agency named from them, came in the first place from some such deposit of white marl.

Wells in Becker county.

Carsonville. Wells on the Second and Third prairies are 20 to 40 feet deep in gravel and sand, sometimes entering till below.

White Earth Agency. A well at the agent's house went 105 feet in till, obtaining water which rose from the bottom about fifty feet.

Erie. Obadiah Sims; sec. 34: well, 38 feet; soil, 2; gravel and sand, 30; very hard, gray till, 6 feet and continuing below; water scanty.

Burlington. A. P. Hall; sec. 8: water formerly stood, during wet weather, in a depression near Mr. Hall's stables; but he dug there twelve feet through yellow till or boulder-clay, at that depth coming to a thick deposit of sand, into which the water is drained away. This is among very numerous and irregular hills and knolls of morainic till, containing frequent boulders of all sizes up to six feet in diameter.

J. A. Philbrick; sec. 14: well, 35 feet; soil, with scattered boulders, 3 feet; and stratified gravel and sand 32 feet, to water. This is at the east edge of the western morainic belt.

William Chilton; sec. 26, a third of a mile northwest from Frazee City: well, 26 feet; soil, 2; sand and gravel, 10; and till, 14, yellowish in its upper part, dark bluish near the bottom, also continuing deeper.

Richwood. The following wells are in the western township. A. S. Blowers; sec. 2: well, 32 feet; soil, 2; yellow till, 10; sand, about an inch; dark bluish clay, probably till, yet soft and easily spaded, very sticky, 20 feet; water came in a vein of sand and gravel at the bottom, from which it rose six feet. Several pieces of lignite were found in the last foot of this well.

Swan Johnson; sec. 8: well, 35 feet; soil, 2; yellow till, 18; sand, one foot thick in the side of the well, thinning out to nothing at the opposite side; blue till, harder than the yellow, 12; and sand with water, 2 feet.

Charles Norberg; in the same sec. 8: well, 15 feet; soil, 2; yellowish till, 12; and sand with water, 1 foot.

Detroit. Wells in the city are 20 to 40 feet deep in gravel and sand, finding an abundant supply of water. An example is J. A. Bowman's well, 35 feet deep: soil, 1½; a hard, ferruginous layer of fine gravel and sand, 1 foot; gray gravel, 2; another rather hard layer of sand and gravel, 1½; nearly white sand, 2; and irony gravel, with pebbles and cobbles up to six inches in diameter, with interstratified beds of yellow sand, 27 feet, to water.

A well on Mr. Bailey's land in sec. 32, went 70 feet; being gravel and sand, 18; and blue till, 52, containing no sandy veins and yielding no water, so that this well was given up. Another well forty feet farther west found a copious spring 18 feet below the surface, probably in a slight depression of the underlying till, such as to determine the course of the drainage from the overlying porous modified drift. The locality is about twenty feet above Long lake, which lies on the west.

Hamden. E. N. Jellum, in the north part of this township, has a flowing well, the water rising from its bottom, about 100 feet below the surface.

John Kroll's well in sec. 28, is about 75 feet deep, all in till. An artesian flow of water rose immediately from a bed of sand and gravel at the bottom. When confined in a pipe, the water comes to a level fourteen feet above the surface. It is softer than that of the ordinary shallow wells thereabout.

Thomas Pierce, in sec. 26, bored 92 feet, through soil, 2; yellow till, 6; and harder dark bluish till, 84; no sandy layers were found, and no water, excepting an unreliable supply from the upper till, very scanty or failing in dry seasons.

Audubon. Mr. H. H. Russell of Alexandria reports the following wells in this township. The town well in the village was yellow till, about 15 feet; and blue till, about 45 feet. At 60 feet a bed of gravel was struck, containing water under such pressure that it suddenly lifted the six hundred pounds of auger and shafting twenty feet, filling the lower eighteen feet of the boring, twelve inches in diameter, with gravel. In three minutes the water rose to its permanent level, two feet below the surface.

William H. Irish's well in this village, on a little higher ground, was guarded from the accident experienced in the town well, by keeping the hole filled with water while boring. Water was found at about the same depth, and rose from the bottom to six feet below the surface.

Rasmus Boye; sec. 7: well, 110 feet; till, about 70 feet, yellow and having its usual characters in the upper part, but dark, very tenacious, nearly destitute of grit and gravel, yet containing occasional cobbles and boulders, with fragments of lignite, in its lower part; then, from the depth of about seventy feet to the bottom, were 40 feet of blue shales, variously tinted, some dark and others lighter in color, probably Cretaceous beds.

Joseph R. Marshall, sec. 19, on a swell of land forty or fifty feet above a large lake near on the east: well, 118 feet; yellow till, 22; iron-rusted gravel and sand, 5; yellow till again, 10; dark bluish till, nearly like the lower part of the till in Mr. Boye's well, 43; dry gray sand, 26; blue till of lighter tint, more sandy and harder than that above, 12; underlain, as was thought, by a bed of hard rock, which prevented further boring; no water was obtained.

Lake Eunice. L. G. Stevenson; N. W. ¼ of sec. 32: well, 82 feet; soil, 2; clayey sand, 3; and sand and fine gravel, 77, to water, in quicksand, supposed to be at the level of the neighboring lakes.

Cuba. Nils T. Sanvigen; sec. 6: well, 37 feet; soil, 2; hard, yellow till, picked, 28; dark bluish till, partly streaked with yellow, 7; water rose seven feet from sand at the bottom.

Lake Park. The town well in the village, 91 feet deep, was yellow till, 40; dark bluish, soft and sticky till, holding frequent cobbles and boulders but only little finer gravel, 51; water rose fifty-six feet from gravel at the bottom. This and the next, like the wells in Audubon, are reported by Mr. Russell.

Rev. K. Bjorgo's well, twenty or thirty rods from the preceding, had the same section to this depth, but water did not rise above the gravel at the bottom. The boring was therefore continued twenty-four feet lower, to a total of 115 feet, going in this lower part through 10 feet of gravel, in which two-thirds of the pebbles are limestone, and then 14 feet in more sandy and harder, lighter-colored but still bluish till. No additional supply of water was obtained. Numerous fragments of lignite were found in the limestone gravel.

MATERIAL RESOURCES.

Agriculture must be the chief industry and source of wealth here. In a former part of this chapter the soil and the ample supply of timber have been noticed. The beautiful lakes, picturesquely hilly tracts, and generally cool and invigorating summer temperature of this district, seem likely to make it a favorite resort for such as seek rest and renewal of health and energy in summer vacations. To the sportsman, also, the fish of these lakes and the deer and other game of the primeval, pathless woods that still remain in the central and eastern parts of the county, offer attractions unsurpassed by any other section of the state.

Water-powers utilized at the time of this survey in 1879 were as follows:

R. L. Frazee's mills, manufacturing flour and lumber, on the Otter Tail river at Frazee City, having a head of twelve feet.

On the Pelican river the Detroit flouring mills, about a mile southeast from Detroit, with ten feet head; and Milton's flouring mill in the southwest corner of Lake View, having about eight feet head.

The Cormorant flouring mill, on the outlet from Cormorant lake, with twelve feet head.

The Richwood mills, manufacturing flour and lumber, on the Buffalo river a short distance below Buffalo lake; head, ten feet.

E. M. Britts & Co.'s mill, manufacturing flour and lumber, on the Straight river at Carson City; head, fifteen feet, raising Straight lake five feet. There is said to be another valuable power on the Straight river within three miles below this; and other good water-powers are available on all the larger streams, especially on the Otter Tail river, which might be made reliable in the driest seasons by using its numerous lakes as reservoirs.

Lime. The drift boulders and blocks of magnesian limestone that have been before mentioned, furnish inexhaustible material for the manufacture of lime. Shaw & Martin burn several hundred barrels of lime yearly at Detroit and at the locality before described three miles west of the White Earth Agency. They have gathered much limestone for this use between one and two miles south of Audubon. About five-sixths of this lime is white and the remainder is yellowish. It is sold at $1.50 per barrel.

Christian Peterson in section 4 of the west township of Richwood, and Daniel Keech in section 14, Lake Park, have also burned lime.

Bricks. In Detroit, about a third of a mile south of the town, Shaw & Martin began brick-making in 1878. The clay used seems to be an alluvial deposit, as it contains small gasteropod shells of recent fresh-water species. Its thickness is three or four feet; and it is underlain by sand and gravel. An intermixture of some sand is required for tempering, and the grains of limestone in the sand cause the bricks to be more or less damaged by a multitude of fine cracks, made by the slacking and consequent swelling of the lime particles after the bricks have been burned. The color of these bricks varies from yellowish near the fire to red in the outer part of the kiln.

In 1879 a kiln of 50,000 bricks was made by Mr. Thomas J. Martin at the White Earth Agency, about fifteen rods northeast from the agent's house. The clay used there was the two or three feet next to the black soil on the lower part of a slope of till, some fifteen feet above a lake which lies near by on the north and northwest. This superficial portion was found to be nearly free from gravel; but the clay at a greater depth could not be used because of its gravelly character, with much limestone. The sand used for tempering, in the proportion of one part to two of the clay, was brought from sandy kame-like knolls south of the lime-kiln three miles farther west.

ABORIGINAL EARTHWORKS.

Three artificial mounds, from eight to twelve feet high, are situated about a mile southeast from Detroit, near the shore of Detroit lake.

CHAPTER XXX.

THE GEOLOGY OF CLAY COUNTY.

BY WARREN UPHAM.

Situation and area. Clay county (plate 61) lies in northwestern Minnesota, adjoining Dakota, from which it is separated by the Red river of the North. Moorhead, the county seat and largest town, is distant 210 and 220 miles, respectively, to the northwest from Minneapolis and Saint Paul. Barnesville, Sabin, Glyndon, Muskoda and Hawley are important villages. Fargo, situated on the west side of the Red river opposite Moorhead, is one of the largest cities of Dakota.

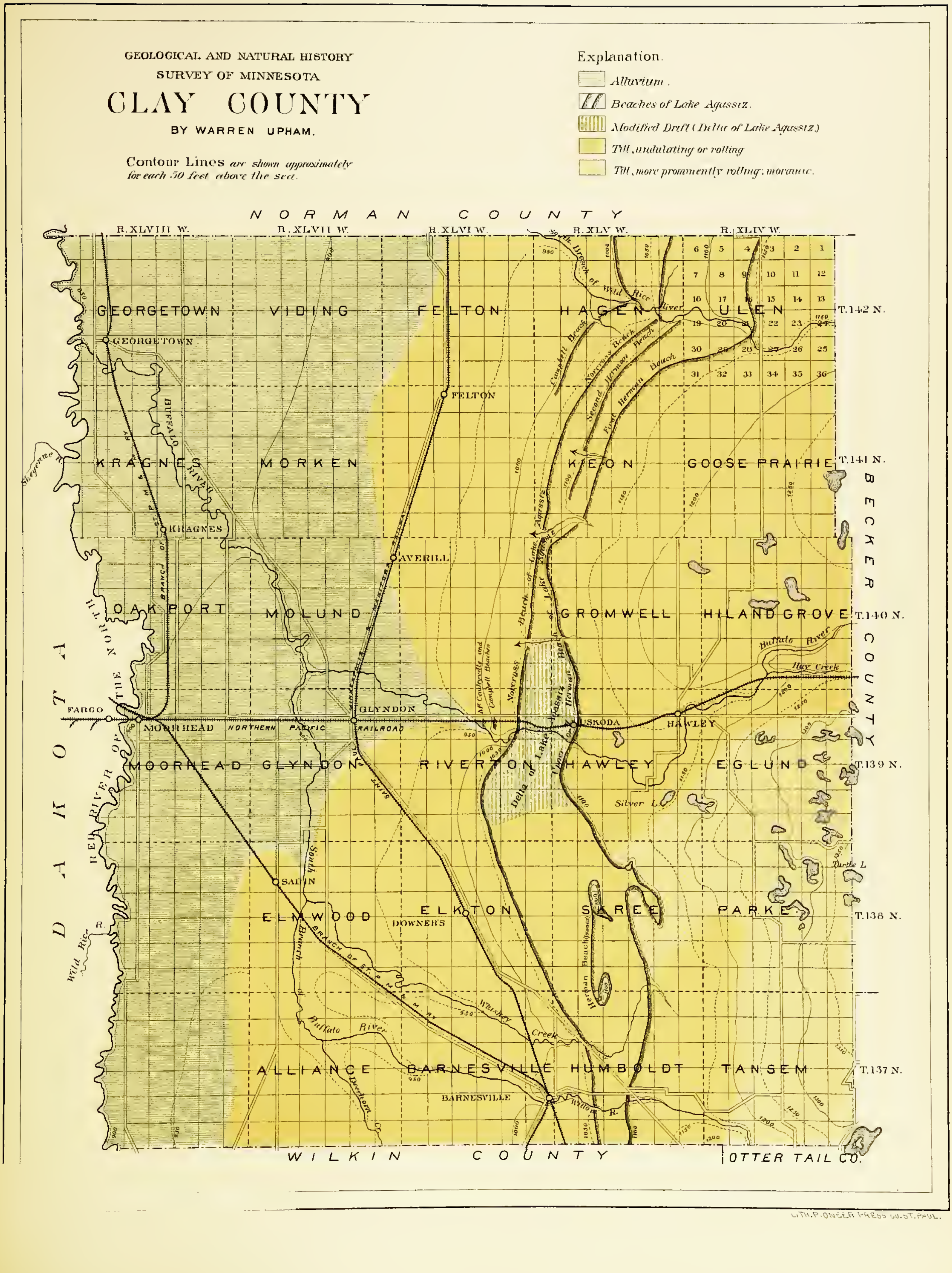
The length of Clay county from north to south is 36 miles, and its width is from 28 to 31 miles. Its area is 1,067.36 square miles, or 683,108.82 acres, of which 14,984.16 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county is drained by the Red river and its tributaries, the Buffalo and Wild Rice rivers. Only the South branch of the Wild Rice lies in Clay county. The Buffalo river has its sources near the center of Becker county, thence flowing westerly to Glyndon, near which place it receives the waters of its South branch, beyond that point flowing northwest to its mouth in Georgetown.

Lakes. On the western two-thirds of Clay county which were covered by the glacial lake Agassiz, the drift deposits and alluvium are spread with a very slightly undulating or quite flat surface that has no hollows holding lakes, though it has slight depressions occupied by sloughs or marshes, in some cases extending several miles. The smoothly undulating or rolling high land farther east bears numerous lakelets of various sizes up to one or two miles in length. They are most frequent in Hawley, Hiland Grove, Eglund and Parke.

Topography. In the foregoing paragraph concerning lakes, the very simple


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
CLAY COUNTY
BY WARREN UPHAM.
Contour Lines are shown approximately for each 50 feet above the sea.
Explanation.
Alluvium.
Beaches of Lake Agassiz.
Modified Drift (Delta of Lake Agassiz.)
Till, undulating or rolling
Till, more prominently rolling; morainic.
NORMAN COUNTY
R. XLVIII W.
R. XLVII W.
R. XLVI W.
R. XLV W.
R. XLIV W.
GEORGETOWN
VIDING
FELTON
HAGEN
ULEN
T. 142 N.
KRAGNES
MORKEN
KEEON
GOOSE PRAIRIE
T. 141 N.
OAKPORT
MOLUND
GROMWELL
HILAND GROVE
T. 140 N.
MOORHEAD
GLYNDON
RIVERTON
HAWLEY
EGLUND
T. 139 N.
ELMWOOD
ELKTON
SKREE
PARKE
T. 138 N.
ALLIANCE
BARNESVILLE
HUMBOLDT
TANSEM
T. 137 N.
WILKIN COUNTY
OTTER TAIL CO.
BECKER COUNTY
DAKOTA
RED RIVER OF THE NORTH
FARGO
MOORHEAD
NORTHERN PACIFIC RAILROAD
GLYNDON
USKODA
HAWLEY
GEORGETOWN
FELTON
KRAGNES
AVERILL
SABIN
DOWNER'S
BARNESVILLE
Buffalo River
Wild Rice River
Sheyenne R.
Wild Rice R.
Hay Creek
Whiskey Creek
Willow R.
Deerhorn Cr.
South Branch of Buffalo River
South Branch of Wild Rice River
Silver L.
Turtle L.
Campbell Beach
Norcross Beach
Second Herman Beach
First Herman Beach
Beach of Lake Agassiz
Delta of Lake Agassiz
Herman Beach
Norcross
McCauleyville and Campbell Beaches
LITH. PIONEER PRESS CO. ST. PAUL.

contour of this county has been described in a general manner. The flat plain on the west is part of the widely known Red river valley. This expanse has an exceedingly flat surface, sloping imperceptibly northward, as also from each side to its central line. The Red river has its course in this axial depression, where it has cut a channel 20 to 60 feet deep. It is bordered by only few and narrow areas of bottomland, instead of which its banks usually rise steeply on one side and by moderate slopes on the other to the plain which thence reaches nearly level ten to twenty-five miles from the river. Its tributaries cross the plain in similar channels, which, as also the Red river, have occasional gullies connected with them, dry through most of the year, varying from a few hundred feet to a mile or more in length.* Between the drainage lines, areas often five to fifteen miles wide remain unmarked by any water courses. The highest portions of these tracts are commonly from two to five feet above the lowest.

In crossing the vast plain of this valley on clear days, the higher land at its sides, and the groves along its rivers, are first seen in the distance as if their upper edges were raised a little above the horizon, with a very narrow strip of sky below. The first appearance of the tree-tops thus somewhat resembles that of dense flocks of birds flying very low several miles away. By rising a few feet, as from the ground to a wagon, or by nearer approach, the outlines become clearly defined as a grove, with a mere line of sky beneath it. Besides this mirage, the traveler is reminded, in the same manner as at sea, that the earth is round. The surface of the plain is seen only for a distance of three or four miles; houses and grain-stacks have their tops visible first, after which, in approaching, they gradually come into full view; and the highlands, ten or fifteen miles away, forming the side of the valley, apparently lie beyond a wide depression, like a distant high coast.

The prominent topographic features of all this region are doubtless due to the form of the underlying rock-surface, upon which the drift is spread in a sheet of somewhat uniform thickness. Erosion, before the ice age, had sculptured the rocks which are everywhere buried and concealed under this universal drift-sheet, and had formed the broad nearly level depression of the

*A gully of this kind has been formed in the northeast part of the city of Moorhead within a few years past, being mostly channeled in an unusually heavy rain-storm soon after the beginning of building there. It is ten to twenty feet deep and twenty to fifty feet wide, with perpendicular sides. It extends about a half mile in a northwesterly course, reaching the Red river a half mile northeast from the Northern Pacific railroad bridge. By its gradual widening, it has outgrown some of the bridges built over it.

Red river valley, which is 1,000 to 800 feet, from south to north, above the sea. Slopes and terraces of these rocks beneath the drift cause the rise eastward from this valley to the lake-sprinkled plateau, 1,300 to 1,600 feet above the sea, which reaches from Glenwood, Alexandria and Fergus Falls, to the sources of the Mississippi. For example, though the traveler finds no ledge of rock in going from the Red river at Fargo and Moorhead seventy-five miles east-northeast to Itasca lake, it is yet almost or quite certain that the form of the surface, marked by two remarkable terraces, is due to that of the bed-rocks, which probably are Cretaceous shales under the Red river plain and strata of Cambrian limestone and sandstone farther east. The flat of the Red river valley extends from Moorhead to about six miles east of Glyndon, with a slight ascent of about fifty feet in these fifteen miles. The next two or three miles rise two hundred feet to the top of a terrace which reaches from south to north the whole length of the Red river valley in Minnesota, though it is not all the way so distinct nor so high as here. Beyond this ascent the surface is again nearly level, being a sheet of slightly undulating or rolling till, with a rise of perhaps four or five feet per mile, through twenty-five miles eastward. Next is a terrace, also reaching a long distance from north to south, which is ascended in three or four miles, rising about three hundred feet, to the White Earth Agency, which thus commands a very extensive western prospect. Thence a more rolling plateau extends, with little change in the average hight, thirty miles eastward to Itasca lake.

In like manner the elevation of the Coteau des Prairies in southwestern Minnesota, 1,500 to 2,000 feet above the sea, and the terrace-like ascent at the west side of the flat Red river valley in Dakota, lying at a distance of twenty to thirty miles west of the Red river, and stretching from the south bend of the Cheyenne river north to the British line where it is called Pembina mountain, are undoubtedly due to the contour of the bed-rocks, probably there shales of the later Cretaceous and Laramie periods, rather than to differences in the thickness of the drift, by which the older formations are covered.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, Saint Paul.

	Miles from Saint Paul.	Feet above the sea.
Hay creek, bed, 1202; grade - - - -	224.2	1207
Hay creek, bed, 1167; grade - -	226.5	1180
Buffalo river, bed, 1150; grade	227.4	1166

	Miles from Saint Paul.	Feet above the sea.
Buffalo river, bed, 1143; grade	228.1	1157
Buffalo river, bed, 1140; grade	228.7	1152
Buffalo river, bed, 1133; grade	229.9	1143
Buffalo river, bed, 1131; grade	230.2	1146
Hawley	230.4	1151
Summit, cutting 5 feet; grade	231.5	1193
Upper or Herman beach of lake Agassiz, crest, 1114; grade	234.6	1100
The cut through this beach deposit of gravel and sand extends 600 feet. The natural surface for two-fifths of a mile east from this beach is 1097 to 1100. Thence a gradual ascent eastward passes above the level of the crest of the beach at a distance of three-fifths of a mile from it.		
Muskoda	234.9	1090
Buffalo river, bed, 940; grade	239.0	957
There is no ascent west of this river, the grade all the way thence to Glyndon being lower than on the bridge.		
Glyndon	243.4	925
South branch of Buffalo river, bed, 896; grade	245.5	917
Moorhead	252.0	906
Red river, bed, 864; low water, 869; usual high water, 895 to 900; extreme high water in exceptional years, 903; grade	252.2	905
Fargo	252.7	905

From the bridge crossing the Red river a level grade extends twelve and a half miles west.

Elevations, Saint Paul, Minneapolis & Manitoba railway.

From profiles in the office of Col. C. C. Smith, engineer, Saint Paul.

a. *Red river valley line in Minnesota.*

	Miles from Saint Paul.	Feet above the sea.
Barnesville	217.5	1018
Willow river (more commonly called Whiskey creek), water, 992; grade	217.9	1007
Junction of branch to Moorhead	218.5	998
Sieber's creek, water, 977; grade	220.2	987
Buffalo creek, water, 955; grade	222.8	961
Glyndon, crossing Northern Pacific railroad	234.9	925
Buffalo river, bed, 905; water, 910; grade	236.5	923
Averill	241.6	919
Felton	249.2	917
Borup, close north of the line between Clay and Norman counties	254.7	913

b. *Barnesville to Moorhead (continuing as the Red river valley line in Dakota).*

	Miles from Saint Paul.	Feet above the sea.
Junction a mile north of Barnesville	218.5	998
Sabin	231.9	928
Moorhead	241.0	903

c. *Moorhead & Northern branch.*

	Miles from Saint Paul.	Feet above the sea.
Junction in east part of Moorhead	241.0	904
Kragnes	249.0	890
Buffalo river, low water, 851; high water, 870 to 880; grade	255.4	882
Georgetown	255.8	882

The following elevations of the Red river are derived in part from these railroad profiles, and in part from a survey of this river by the United States engineer corps under the direction of Capt. C. J. Allen.

Red river of the North, ordinary low water.

	Feet above the sea.
At the southwest corner of Clay county (Highest floods, about 910.)	885
Mouth of the Wild Rice river of Dakota	874
At Moorhead and Fargo (Highest floods, 893.)	869
Mouth of Cheyenne river	856
Mouth of Buffalo river (Highest floods, about 880.)	850

The extremes of elevation in this county are 1,350 feet for the highest swells and hills on the east border of the county in Hiland Grove, Eglund, Parke and Tansem, and 850 feet on the shore of the Red river in Georgetown. Estimates of the average hights of townships are as follows: Ulen, 1,150 feet; Goose Prairie, 1,220; Hiland Grove, 1,240; Eglund, 1,250; Parke, 1,275; Tansem, 1,250; Hagen, 1,050; Keon, 1,125; Cromwell, 1,175; Hawley, 1,150; Skree, 1,120; Humboldt, 1,090; Felton, 925; T. 141, R. 46, 960; T. 140, R. 46, 980; Riverton, 1,000; Elkton, 990; Barnesville, 980; Viding, 900; Morken, 910; Molund, 910; Glyndon, 925; Elmwood, 940; Georgetown, 890; Kragnes, 890; Oakport, 900; Moorhead, 910; T. 138, R. 48, 915; T. 137, R. 48, 920. The mean elevation of Clay county, derived from these figures, is approximately 1,030 feet above the sea.

Soil and timber. The black soil averages two feet thick. It is easily cultivated and very fertile. Wheat is the staple export, but all other crops proper to this latitude are profitably raised. Miscellaneous agriculture, market gardening, stock-breeding and dairying, will eventually acquire prominent rank, with subdivision of the land into small farms, as the county becomes more fully populated. At present, nearly all the great plain of the Red river valley is made a great wheat-field, and the plowing, seeding and harvesting on some of the immense farms are very impressive sights, the workmen and teams being marshaled in nearly as regular order as the battalions of an army.

With small exceptions, this county is wholly prairie. In the east part, timber occurs about the shores of the lakes and occasionally forms groves that extend a half mile or more on the rolling and hilly uplands, the largest of these timbered tracts being in the central part of Eglund. The Red river is continuously fringed with timber, and its larger tributaries have their course marked in the same way. The growth of wood is here confined mostly to the banks of the streams. The trees and shrubs which thus occur along the Red and Buffalo rivers in northwestern Clay county, are stated by Mr. Adam Stein, of Georgetown, to be the following: white ash, white and slippery elm, bur oak, ironwood, poplar, box-elder, wild plum, hackberry, prickly ash, frost grape, choke-cherry, red raspberry, rose, thorn, prickly and smooth gooseberries, black currant and hazelnut, more or less common; wild red cherry, Juneberry, high bush cranberry, and cottonwood, rare.

GEOLOGICAL STRUCTURE.

The bed-rocks, casually discussed in an earlier part of the chapter as to their probable influence on the topography, have no outcrops in this county, being heavily overlain by drift. A well at Fargo, however, went below the drift into shales and sandrock, which are probably of Cretaceous age, like the similar formations that occupy the greater part of Dakota. The first 95 feet were clay, stratified in its upper part, but perhaps till for some portion below; next was a layer of gravel, 10 feet; then till, 115 feet; beneath which the remaining 42 feet, supposed to be Cretaceous deposits, were soft, dark blue shale, 32 feet; coarse sandrock, 6 feet; and a second shale, 4 feet, in which the well stopped at a total depth of 262 feet.*

Capt. J. H. Smyser of Riverton states that a cut made for the Northern Pacific railroad near the northeast corner of section 10 in that township encountered numerous large slabs and blocks of limestone, which he supposed to be part of a ledge. It was in the bottom of the east part of the cut, and is said to have been covered by ballast when the track was laid.

Glacial and modified drift. The average thickness of the drift deposits is probably about one hundred and fifty feet. Boulder-clay or till, having the same general characters as in the basin of the Minnesota river and throughout all the western and southern portions of the state, forms most of the surface upon the eastern two-thirds or three-fourths of this county, including much of the Red river valley plain, on which it reaches to varying limits five to ten miles east of the river. Rarely small kame-like knolls of gravel and sand are observed on the surface of the till east from the upper beach of lake Agassiz.

In gravel of the modified drift, containing pebbles up to one and a half

*Report of U. S. geological survey of the territories, 1872; page 301.

inches in diameter, the following proportions were found: at Hawley, 125 pebbles of limestone to 70 of granite and other crystalline rocks; and at Muskoda, 44 of limestone to 36 of the granitic. The limestone pebbles are most abundant in number, but in total volume they are only about equal to the granitic pebbles. Of the larger boulders in the till, however, probably on an average nineteen-twentieths are granites, syenites, gneisses and crystalline schists.

A forest-bed found in Mr. Marth's well in Barnesville, overlain by twelve feet of till, situated about 1,000 feet above the sea, much lower than the Herman and Norcross beaches of lake Agassiz, indicates that in the midst of the great ice age there was an interglacial epoch, when a warm climate melted away the ice far enough to drain this valley northward. Another well in Mitchell, Wilkin county, reported in a preceding chapter, gives similar testimony.

Lacustrine deposits. The shore-lines of lake Agassiz are marked by low, gracefully rounded beach-ridges of gravel and sand. The upper or Herman beach is well exhibited a quarter of a mile east of Muskoda station. It is a ridge of interbedded gravel and sand, thirty-five rods wide and fifteen feet high, with its top 1,114 feet above the sea. A fine section is exposed by its excavation for railroad ballast, showing the stratification to be mainly level, but inclined at the sides parallel with the gently sloping surface. This beach-ridge or bar is separated from the higher land eastward by a depression about fifteen feet deep and nearly a half mile wide.

Next west of this ridge, at Muskoda station and onward, the Northern Pacific railroad cuts through a thick and extensive deposit of sand, with beds of gravel and clay in some portions, constituting a plain about two miles wide. This extends three miles to the north and also occupies an equal tract south of the Buffalo river, which here enters the area formerly covered by lake Agassiz. These beds, declining slightly toward the west, have their surface 1,075 to 1,100 feet above the sea, being 100 feet below the adjoining uplands on the east, and 150 feet above the plain of the Red river valley, which begins within one or two miles farther west and extends fifteen miles to the Red river. They appear to be the delta brought down by the Buffalo river and spread in the side of the lake at its mouth. Since the drainage of the lake the river has excavated a large gap through this deposit.

The formation of this delta by the Buffalo river, while the Red river where it entered lake Agassiz in southwestern Otter Tail county and the Wild Rice river in Norman county formed no appreciable deposits of this kind, must apparently be due to the outlines of the ice-sheet and the position and trends of its margin at times of halt and of rapid retreat during its final melting. On account of these conditions large deposits of modified drift were supplied to form deltas by some of the streams tributary to lake Agassiz, while very little was brought by others. The Sand Hill river in the south edge of Polk county deposited in the lake a similarly massive delta, consisting chiefly of fine sand, which is blown by the wind into dunes that occupy an area of three or four square miles. In Dakota a remarkable delta,* also blown into conspicuous dunes, was brought into lake Agassiz by the Cheyenne river southwest of Fargo; and in Manitoba the delta of the Assiniboine river forms a large area of sand hills and dunes, which extend some fifty miles along the north side of the Assiniboine next below the mouth of the Souris river.

Alluvium. The thickness of the alluvial beds that form the surface of the flat Red river valley for a width of five to fifteen miles from the river, has perhaps been in some instances overstated in the reported sections of wells, because of the liability that the transition to underlying till might fail to be noticed, the latter being also clay, similar in color and differing from the stratified clay chiefly in containing some intermixture of gravel and boulders, which indeed are so scanty in the till of western Minnesota that often they are hardly noticeable in well-boring. It seems probable that the greatest thickness of the stratified alluvial clay along the central depression of the Red river valley varies generally from 60 to 90 feet, though doubtless in some portions of the valley exceeding 100 feet, and that the depth assigned to this deposit in wells may often include some thickness of the underlying till. Whatever till was contained in the ice-sheet and allowed to fall in the water of lake Agassiz as the ice melted away, would evidently be soft to bore through, perhaps not harder than beds of alluvial clay deposited over it; but till that lay beneath the ice-sheet would be much harder. The borings reported at Glyndon seem to give reliable evidence that the alluvium and englacial till, the latter probably not exceeding twenty-five feet in thickness, there measured together 100 feet, an unusual depression in the sheet of till having been filled by the silt of the Buffalo river and its South branch.

One of the wells in alluvial beds at Glyndon is specially interesting because it shows remains of vegetation and drift wood at the depth of 13 to 18 feet; and the two borings at G. S. Barnes & Co.'s elevator in this village found a log and decaying fragments of wood at the depth of 35 feet. These deposits, like the similar vegetal layer found still deeper in the stratified clay of this valley at McCauleyville in Wilkin county, prove that the deposition of these sediments was from rivers in their stages of flood, after lake Agassiz was drained to Hudson bay.

Lake Agassiz. Detailed notes of the survey and determinations of the elevation of the beaches of lake Agassiz are as follows:

Upper or Herman beach. Elevation of this beach, a low rounded ridge of the usual character, composed of gravel and sand, at the east side of section 33, Tenney, 1100 feet above the sea. The land thence for two-thirds of a mile east is smooth till, a few feet lower than the beach. Beyond this the next third of a mile northeastward in the north part of section 34, is very rocky with many boulders up to six and rarely ten feet in diameter, the contour being moderately rolling, 10 to 30 or 40 feet above the beach. Farther eastward here and through the next fifteen miles north to the Northern Pacific railroad, the moderately rolling or smoothly hilly till rises 100 to 250 feet above this beach within the distance of about ten miles between it and the east line of the county.

Elevation of the beach-ridge in the east half of section 28, Humboldt, one-fourth to three-fourths of a mile south of Willow river, 1098 to 1100 feet. In the three miles westward to Barnesville, the area that was covered by lake Agassiz shows here and there boulders projecting one to two feet above the surface, which is till, slightly smoothed by the lake.

The beach for three-fourths of a mile north from Willow river consists of a belt of gravel and sand, lying on an eastwardly ascending slope of till. Through the next one and a half miles northward, in the N. W. ¼ of section 22, and in section 15, Humboldt, the shore of lake Agassiz is not marked by the usual beach of gravel and sand, but instead becomes a belt of marshy and springy land, twenty to fifty rods wide, rising by a gentle slope eastward, rough with many hummocks and hollows, in some portions forming a quaking bog, in which horses and oxen attempting to cross are mired.

In the next two miles northward through sections 10 and 3, Humboldt, the beach is nowhere well marked as a ridge, but is mainly a belt of sand and gravel, lying on a slope of till which gradually rises 30 or 40 feet higher at the east. The lack of typical beach deposits on this shore through the north half of Humboldt is probably due to its sheltered situation in the lee of islands on the northwest. The course of the shore-currents, determined by the prevailing winds, seems to have been southward, as on the shores of lake Michigan.

Highest part of the southern island in the east edge of lake Agassiz, in the N. E. ¼ of section 5, Humboldt, extending northward into Skree, 1117 to 1122. This island was about a mile long from south to north. Beach on its west side, a well developed ridge of gravel, near the middle of the north line of section 5, 1095; and for a third of a mile north-northwest from the last, 1094 to 1096. On the east side of this beach, as it continues northward, is a slough two-thirds of a mile long from south to north, and about thirty rods wide, 1085. This was evidently filled by a lagoon, sheltered on the southeast by the island, and separated from the main lake by the beach. Toward the northeast it widened into a shallow expanse of water, eight to fifteen feet deep, about one and a half miles wide, divided from the broad lake on the west by two islands and this beach which connected them together. Lake Agassiz here appears to have stood at the hight of 1090 to 1095 feet.

Beach in the north part of section 32, Skree, a broad, rounded ridge of gravel with pebbles up to three or four inches in diameter, 1103; and through the next half mile, in the south half of section 29, Skree, 1102 to 1104. Along part of this distance the beach is bounded eastward by a steeper descent than usual, the land next east being 1085 to 1090. This beach continues northward in a typical ridge through sections 29 and 20, Skree.

Beach at L. Williams', in the southwest ¼ of the S. E. ¼ of section 20, Skree, 1101; a fourth of a mile farther north, 1106; a half mile north of Mr. Williams', near the middle of the north line of section 20, 1110; continuing a very definite ridge through the south half of section 17, 1109 to 1110.

Near the middle of this section 17, Skree, the beach deposit of gravel and sand ceases at the west side of the northern island, which was situated in the east half of this section and extended also eastward in a long, low projection nearly across the south side of section 16, and northward half-way across section 8. Highest part of this island, in or near the N. E. ¼ of the N. W. ¼ of section 17, Skree, is about 1125. The old shore of the north half of this island has no beach-ridge nor other deposits of gravel and sand; but is plentifully strewn with large boulders up to five and ten feet in diameter, and many of these project two to five feet above the general surface. The lake-waves eroded here, and deposited the sand and gravel gathered from this till as a beach a little farther south.

North and northeast from this northern island, a lower expanse, nearly level and in some portions marshy, resembling the broad flat valley of the Red river, extends one and a half miles to the east shore of lake Agassiz, its hight being 1075 to 1090, or ten to twenty-five feet below the surface of the ancient lake. The distance between these islands was two miles, and the distance from the summit of the first to that of the second, nearly due north almost four miles. Each of them rose about twenty-five feet above lake Agassiz. The strait between them and the mainland eastward was ten to twenty feet deep, and from one to one and a half miles wide, excepting a narrow place near the southeast corner of section 16. East of the northern island the main shore of the lake was indented by a bay a third to a half of a mile wide, and about ten feet deep, stretching two and a half miles southeastward from the lake at the northwest corner of section 10, to the west part of section 23, Skree. The shore of the lake east of its islands, along this bay, and northwesterly to the north line of this township, lacks the beach deposits which elsewhere distinguish it.

In its continuation northwestward the shore-line of the old lake runs diagonally across section 32, Hawley, where it again presents the anomalous character of a very springy and marshy belt twenty to forty rods wide, rough with hummocks and in many places so deeply miry that it is dangerous for teams. This boggy tract has a gentle descent westward, its lower portion being 1085, and its upper border, very nearly level across this whole section, being 1098 to 1100, which was almost exactly the hight of lake Agassiz, as shown by its distinct beach of gravel and sand at the south and north. Next eastward rises a moderately undulating slope of till, strewn with abundant boulders; and rarely a boulder, two to five feet in diameter, is seen on the springy land that marks the border of the ancient lake.

The delta brought into the east side of lake Agassiz by the Buffalo river extends about five miles southwestward from Muskoda, forming a continuously descending plain of stratified sand and fine gravel, declining from 1100 near Muskoda to 1073 at its southwestern limit in the north part of section 34, Riverton. Here, and northward along a distance of three miles to the Buffalo river, this delta-plain is terminated by a steep slope, like the face of a terrace; the outer portion of the original delta, beyond this line, has been carried away by the waves and shore-currents of the lake when it stood at the lower level marked by the Norcross beach.

Threshold of church a fourth of a mile southeast from Muskoda depot, 1113. Beach here and for a third of a mile south to the Buffalo river, as also at the excavation for the railroad, twenty-five rods north of the church, 1113 to 1114. The beach here is thirty-five rods wide, rising fourteen or fifteen feet, in a gentle swell, above the edge of the delta of modified drift on the west, and descending the same amount to the depression at its east side. It is made up of interstratified gravel and sand, the former prevailing, including pebbles up to three or four inches and rarely six or even nine inches in diameter all water-worn. No boulders occur here; nor are they found in any of the beach deposits of lake Agassiz.

Beach in next two miles north of Muskoda, 1113 to 1125; at its lowest depression, about one mile north of Muskoda, 1105; at William Perkins' house, in the S. E. ¼ of the S. E. ¼ of section 30, Cromwell, 1122; an eighth to a third of a mile south-southeast from Mr. Perkins', 1130. A nearly or quite continuous depression, a fifth to a third of a mile wide, lies at the east side of this beach, declining in elevation from 1118 feet near Mr. Perkins' house to 1100 at Muskoda.

The surface of lake Agassiz at Muskoda was 1105 feet, very approximately, above our present sea-level. Within five to ten miles northward, its hight seems to have been 1110 to 1115 feet.

Beach through the north half of section 30, Cromwell, 1128 to 1131; and through the west part of sections 19 and 18, Cromwell, 1125 to 1130, composed of sand and fine gravel, not generally in a typical ridge, but often with a depression two to five feet lower eastward, and bounded on the west by a descent of about thirty feet within an eighth of a mile. A surface of slightly undulating till rises very gradually from this beach eastward.

Beach at a high portion, in or near the S. E. ¼ of section 1, T. 140, R. 46, 1136. For a mile southward from this point it is a finely rounded ridge of gravel, 1130 to 1136. The depression at its east side is four to six feet lower; then the surface gently rises at a fourth to a third of a mile from the beach to 1135 or 1140, beyond which eastward this nearly level, but slightly undulating expanse of till rises only five or ten feet per mile.

Beach a fourth of a mile northeast from the high point mentioned, probably in the N. W. ¼ of section 6, Cromwell, 1128 to 1127. This is an ordinary beach-ridge of gravel and sand, with a depression of two or three feet next east.

Near the south line of section 29, Keon, both the Herman and Norcross beaches, here about two-thirds of a mile apart, are intersected by a water-course. At its north side the upper or Herman beach, near the east line of section 29, and in the N. W. ¼ of section 28, Keon, consists of two well-marked ridges of gravel and sand, some thirty rods apart, and about ten feet above the land eastward and between them. These ridges unite in or near the S. W. ¼ of the S. W. ¼ of section 21, Keon, at the hight of 1130 to 1132 feet.

Beach three-fourths of a mile farther north, probably near the north line of section 21, Keon, a typical gravel ridge, 1134 feet, ten feet above the land next east; but only a sixth of a mile farther north east, this beach-ridge is depressed to 1123 feet.

A lower beach, contemporaneous with the Herman beach farther south, but formed when the surface of the lake in this latitude had fallen slightly from its highest level, is finely exhibited at a distance of one-third to two-thirds of a mile west of the upper beach, through the four miles from the south side of section 20 to the northeast corner of section 4, Keon. The elevation of this secondary beach, in the south part of section 20, is 1115 feet; thence to a stream near the east line of the S. E. ¼ of section 17, 1118 to 1123; at each side of this stream, 1118; northward, in the northwest part of section 16, and in the S. W. ¼ of section 9, 1118 to 1121; and in the north part of section 9, 1121 to 1127.

The elevation of the upper beach in this township, 1123 to 1134, shows that the hight of lake Agassiz here was about 1115 to 1120 feet. The secondary beach was made by the lake after it had fallen six to ten feet.

Surface of ground at Christian Sether's house, in the S. W. ¼ of section 10, Keon, 1129. Upper beach through the west part of this section 10, 1130 to 1137, rising toward the north. This is a typical beach-ridge of gravel, descending in a rather abrupt slope on its east side to land six or eight feet lower, which thence ascends with a slightly undulating surface eastward.

Upper beach in section 3, T. 141, R. 45, 1134 to 1137, ten feet above the land next east. Secondary beach, parallel with this and about three-fourths of a mile distant to the northwest, in sections 4 and 34, 1123 to 1127, being thus ten feet lower than the highest parts of the eastern beach. Extensive sloughs, enclosing lakelets, lie between these beaches in sections 34 and 35, Hagen, at an elevation of 1115 to 1120 feet, but sinking northward to 1105 feet. The secondary beach continues to the northeast corner of section 26, T. 142, R. 45, declining in hight northeastward, as it approaches the South branch of the Wild Rice river, being at 1125 to 1115 feet.

Upper beach in section 35, and in the south part of section 25, T. 142, R. 45, 1140 to 1142. This is a typical beach-ridge of sand and gravel, about thirty rods wide, with the land next southeast five to eight feet lower, and divided from the secondary beach northwesterly by a slough about one mile wide, this slough being at 1115 to 1105 feet.

Beach at B. O. Helde's house, in the south half of the S. W. ¼ of section 30, Ulen, 1138. The flat expanse of the Red river valley reaches east on the South branch of the Wild Rice river to section 16, Hagen, probably there being about 975 feet above the sea, or 160 feet below this upper beach of lake Agassiz, four or five miles southeast.

Beach through sections 30 and 29, Ulen, extending one and a half miles east-northeast from Mr. Helde's to the South branch of the Wild Rice river, in a low, gently rounded ridge of gravel, thirty rods wide, five to eight feet above the area of till next southeast, and about fifteen feet above the surface close at its northwest side, 1138 to 1142, mostly 1140. Beach at Nels Wiger's house, probably in the N. W. ¼ of section 28, Ulen, 1133; about forty rods west from this, 1140.

South branch of Wild Rice river in the S. W. ¼ of section 21, Ulen, 1095.

Beach, typical gravel ridge, in or near the west half of section 16, Ulen, a half mile to one and a half miles north of the South branch, 1140 to 1143; surface of till an eighth to a fourth of a mile next east, 1135. Farther east, the slightly or moderately undulating expanse of till has an average ascent of about ten feet per mile for fifteen miles, to the base of the highland at the White Earth Agency, which is dimly visible, blue, close to the horizon. Westward, the surface gradually descends to the Norcross beach, nearly sixty feet lower, which is the farthest land in sight in that direction, about three miles distant, beyond which lies the flat Red river valley.

Beach, a well-defined ridge, in sections 9 and 4, Ulen, 1139 to 1144; and at a high portion, in or near the S. E. ¼ of the S. E. ¼ of section 33, Home Lake, in the south edge of Norman county, 1149 feet.

Norcross beach. The Norcross beach of lake Agassiz is well exhibited at D. D. Daniels' house, in the S. W. ¼ of the S. E. ¼ of sec. 20, Tenney, about one and a half miles east from Barnesville, being a low, smoothly rounded ridge of gravel and sand, with the elevation of 1061 feet above the sea.

In Riverton township, and in sections 35 and 26, T. 140, R. 46, the eroded western border of the delta of Buffalo river marks the shore of lake Agassiz at the time of the Norcross beach.

In the west part of section 24, T. 140, R. 46, and for four miles northward, the Norcross beach lies a half to three-fourths of a mile west of the upper beach and about fifty feet lower. The terrace which lies between these beaches is strewn with occasional boulders up to six, eight or ten feet in diameter, and rarely of larger size, much more abundant than upon the average surface of the till in this region; indicating that the surface there has been considerably eroded by the waves of the lake. The largest boulder seen in this county lies about fifty rods west of the upper beach in or near section 12, T. 140, R. 46. Its dimensions are 15 by 12 by 5 feet, and its top is 1095 feet above the sea. It is gneiss, minutely porphyritic with white feldspar crystals up to an eighth or a fourth of an inch long.

The elevation of the foot of the western slope of the upper or Herman beach along the north part of the east line of this T. 140, R. 46, is 1095 to 1100 feet. Crest of the Norcross beach in section 12, T. 140, R. 46, six miles north of Muskoda, 1080; and along the distance of three miles through sections 13, 12 and 1, it varies from 1075 to 1085 feet. In section 31, T. 141, R. 45, its hight is 1085 feet. Like the Herman beach, it is a low, smoothly rounded ridge of gravel and sand, usually having a depression of three to five feet or more at its east side.

Through the west part of T. 141, R. 45, the Norcross beach is one to one and a half miles west of the upper beach. Thence it crosses T. 142, R. 45, in a north-northeast course, lying two to three miles northwest and west of the upper beach. Its hight in these townships is approximately 1080 feet.

Campbell and McCauleyville beaches. These lower beaches of lake Agassiz are respectively 1002 and 983 feet above the sea where they are crossed by the Northern Pacific railroad in Riverton between three-fourths of a mile and one and a half miles east from the Buffalo river bridge. In the north edge of the county, they extend through the central part of T. 142, R. 45, in a northeast and north course, lying one to two miles west of the Norcross beach. Their elevations were not determined in this township, but they are probably about five feet higher than in Riverton.

Along the course of these beaches, where the first appreciable ascent is made above the plain of the Red river valley, the surface of the till is strewn with many boulders, chiefly granitic, of all sizes up to five or rarely ten feet in diameter. They are about as numerous as is usual where twenty to forty feet of till have been removed by excavation, as for grading; the boulders that were contained in the till being left scattered over the surface. A similar amount of erosion was probably effected by the lake-waves along many parts of this shore during the stages of the Campbell and McCauleyville beaches. Only in few places, however, is a steep escarpment observable, such as is formed by undermining waves; hence it is probable that most of the erosion was done in the shallow margin of the lake, beneath its surface. Thereby the sand and gravel of the beaches was obtained, and the descent immediately bordering them on their lakeward side was increased, while the clay of this erosion sank in the more still, deep portions of the lake. The boulders mentioned cannot be supposed to have stranded from floating ice; for then they would occur to some extent in some of the beach and delta deposits.

Wells in Clay county.

Ulen. Reier Severson; sec. 26: well, 25 feet; soil, 2; all below is yellow till, with no veins of sand or gravel; water seeps.

B. O. Helde's well, in the S. W. ¼ of sec. 30, on the upper or Herman beach of lake Agassiz, is 10 feet deep in gravel and sand.

Goose Prairie. Andrew Herseth; sec. 28: well, 30 feet; soil, 2; yellow till, picked, 16; and sand, 12 feet, to water.

Hiland Grove. Iver Iverson; sec. 10: well, 18 feet; soil, 2; yellow till, 6; and fine yellow sand, 10.

Peter Hanson; sec. 11: well, 24 feet; soil, 2; yellow till, spaded but hard, 16; and sand, 6 feet, to water.

Parke. Dr. Charles Sill, living in sec. 7, states that the prominently rolling land in the east half of this township, though generally till or boulder-clay on the surface, is found in many places to be underlain at a slight depth, sometimes less than five feet, by thick deposits of sand. The last three wells foregoing, and numerous wells and sections in the western ranges of Otter Tail county, similarly show modified drift overlain by till of no great thickness. Some discussion of their mode of deposition is given in the report of Otter Tail county.

T. 141, *R.* 45. Christian Sether; S. W. ¼ of sec. 10: well, 22 feet; soil, 2; yellow till, picked, 18; and gravel and sand, 2 feet and continuing deeper; water rose three feet above the top of the gravel. This is about twenty rods east of the upper beach of lake Agassiz, which is found by excavations to be gravel and sand, to a depth of at least six feet.

Cromwell. David France; N. E. ¼ of sec. 8: well, 14 feet; yellow till, mostly picked, 12; and gravel and sand, 2 feet, containing water.

William Perkins; S. E. ¼ of sec. 30: well on the upper or Herman beach of lake Agassiz, 12 feet, all gravel and sand.

Hawley. Andrew Wilson; sec 4: well, 54 feet; soil, 2; hard, yellow till, 18; coarse gravel, water-washed, nearly all pebbles up to six inches in diameter, with scarcely any sand, 2 feet; sand, coarse above but very fine below, 8; again, yellow till, with streaks of whitish calcareous matter, 20; a darker, very hard, clayey layer, 6 inches; quicksand, with water which does not rise, 6 inches; and dark, iron-rusted till, very hard, 3 feet and below.

Walter Shave; sec. 10: well, 72 feet; soil, 2; yellow till, picked, 15; sand, 20; yellow, marly till, 30; a dark bluish, very hard, clayey layer, 1 foot; and gravel, 1 foot, with water which does not rise and therefore required a basin to be dug to hold it, this being in brown, very hard till, 3 feet. The order of deposits found by this well and the preceding is the same. They are about a mile apart. The contour of the region is smoothly rolling, in swells 20 to 40 feet high.

Tenney. D. D. Daniels; S. E. ¼ of sec. 20: well, 25 feet, on the Norcross beach of lake Agassiz; soil, 2; gravel and sand, 2; soft, yellow clay, not gravelly, 4; and again sand and gravel, 17; one to two feet of water.

John H. Sieber's well on the Herman beach near the east side of the N. E. ¼ of sec. 28, is 14 feet deep, all gravel and sand.

Riverton. E. L. Belknap's well, in the N. E. ¼ of section 24, on the delta deposited by the Buffalo river in lake Agassiz, went 23 feet in sand, to water.

Elkton. Abraham Henry; S. W. ¼ of sec. 26: well, 9 feet; soil, 2; yellow clay, 3; gravel and sand, 4, containing pebbles up to two inches in diameter; water plenty and good.

A well at the railroad section-house, about a half mile west of Mr. Henry's, on a swell ten feet above the general surface, is 12 feet deep, all the way in gravel and sand. Another well about three miles farther west is 60 feet deep, mainly in till.

Barnesville. Town well, 22 feet deep; soil, 2; yellow quicksand, 4; hard, dark bluish till, 16 feet and continuing lower; water seeps from the quicksand, filling the well usually half full, not failing in dry seasons.

John Marth; in the village: well, 13; soil (the blackened surface of the till), 2; yellowish till, 10; then, quicksand, 1 foot, containing several branches and trunks of trees, thought to be tamarack, up to eight inches in diameter, lying across the well, which, together with the inflow of water, prevented farther digging.

A well 32 feet deep at the elevator was soil, 1 foot; marly till, 6 feet; sand and gravel, 23; and blue clay, probably till, 2 feet; to water in quicksand, from which it rose twelve feet.

Molund. Ole Lie; sec. 8: well, 30 feet; sand, 15; and stratified clay, 15, gray for the first five feet but dark bluish below.

Glyndon. The well at the railroad engine-house, 21 feet deep, recorded by Prof. Winchell in the sixth annual report, was black soil 1 foot; yellow quicksand, 12 feet; blue quicksand, sheets of turf and vegetable deposits, 3½ feet; blue clay and drift wood, 2 feet; and blue clay, 2½ feet.

On G. S. Barnes' farm about one and a half miles west of the village a well 112 feet deep, bored by Brophy Brothers, is reported by them to have been soil, 3; yellow quicksand, 16; dark bluish clay, free from stones, 30; yellow quicksand again, 6; dark clay, like the preceding, 45; brown, very hard stony clay or till, 10; and gravel, containing pebbles up to two or three inches in diameter, 2 feet, from which water rose and has since stood at a permanent level ten feet below the surface.

Two other borings were made by the Brophy Brothers at the elevator owned by G. S. Barnes & Co. in the town; but these were unsuccessful, not penetrating to water, because of breaking the augers in the till, called "hardpan," at the bottom. In the deeper one of these borings a depth of 125 feet was reached, the section being reported as soil, 3; quicksand, 22; dark clay, free from stones, 75; very hard, yellowish till, 15; and softer till, 10. The till in these borings is said to have been so hard that only a tenth as fast progress could be made in it as in the dark alluvial clay above. A log of wood, which was called "cedar," about a foot in diameter, was encountered by one of these borings in the dark alluvium, thirty-five feet below the surface; and the other boring, about a dozen feet distant, found "rotten chips" of wood at the same depth. This layer is probably continuous with the vegetal deposits found in the well at the engine-house somewhat farther west.

Elmwood. A well at Sabin station, 18 feet deep, was all yellowish, fine clayey and sandy silt, with no gravelly layers; seven or eight feet of water. About twenty rods to the southeast the railroad cuts through a swell of till with frequent boulders up to three feet in diameter and the ordinary proportion of gravel.

C. F. Cornell; N. E. ¼ of sec. 6 in the south township of Elmwood: well, 18 feet; soil, 2; yellow till, 16, and extending lower; water seeps from the bottom standing five feet deep.

Carl Ernst; sec. 32 in this south township: well, 70, seen while being bored at this depth; soil, 2; yellow till, 6; and darker bluish till, 62 feet and continuing below; no layers of gravel and sand; no water.

Georgetown. E. R. Hutchinson; sec. 10: well, 28 feet; soil, 2; yellow clay, 25 feet, containing gravel at least in its lower part and therefore till; sand, 3 or 4 inches, with dark till below; water rose eleven feet in a few hours.

At the former post of the Hudson Bay Company, in the village, a well was dug in 1860 to the depth of 80 feet; it went all the way in clay, perhaps wholly alluvial, yellowish for about ten feet at the top and dark bluish below, containing no sandy layers and supplying no water. Mussel shells are said to have been found in this well ten or twelve feet below the surface.

Kragnes. D. C. Smyth; sec. 20: well, 26 feet; soil, 2; yellowish gray clay, stratified, 8; dark, soft and moist, stratified clay, 15; "black sand," with water, 1 foot, underlain by dark bluish clay; water rose about eight feet.

Moorhead. George M. Richardson, some three miles northeast from Moorhead, has a flowing well, which is reported to have a depth of 100 feet or more.

The common wells in the city are 10 to 20 or 25 feet deep, obtaining an ample supply of water. Throughout Moorhead and Fargo the alluvial clay at a depth varying from six to twenty-two feet encloses a water-bearing bed of sand, which is usually three or four feet thick and occasionally reaches a thickness of ten feet.

At John Erickson's brewery a well 104 feet deep, described by Prof. Winchell in the sixth annual report, was light-colored clay, 20 feet; quicksand, 4 feet; and blue clay, 80 feet, containing gravel and boulders in its lower part; underlain by sand from which water rose immediately about eighty feet.

Fargo. A. H. Moore's well in Fargo, 95 feet deep, within a mile west from the last, was similar, being yellow clay, 15 feet; sand, 3 feet; and dark bluish clay, 77 feet, said to have been free from pebbles and gravel, excepting in its last two feet; underlain by sand from which water rose to seven feet below the surface.

The well at the Pillsbury & Hulbert elevator in the north part of Fargo is 150 feet deep, going through several water-bearing beds, but shutting out the water of these and receiving its supply from a layer of fine, white gravel at the bottom; water softer than that of the Red river rises from this layer to a permanent level eight feet below the surface, coming in such amount that it can not be lowered by pumping.

The water of all this region, not only in wells and springs but also in the streams, is hard because of the carbonates of lime and magnesia which it has dissolved in soaking through the ground. The only practicable way to provide water satisfactory for washing with soap is by collecting the rain from roofs. By the construction of cisterns, this soft water may be kept constantly on hand, there being a good supply of rain in all seasons excepting winter, when it falls as snow. The water of streams and wells also contains a small proportion of the alkaline sulphates of lime, soda and potassa, and carbonate of soda, not generally in sufficient amount to be perceptible to the taste, but enough to cause a more rapid and offensive decay of wood and other organic matters than in the water of wells in parts of the state farther east and south. The wooden well-curbing, commonly pine, which has been often used in this region, soon contaminates the water, and when such wells are left stagnant or only drawn from slightly, the water becomes too foul in smell and taste to be drank, even by cattle, and it may be the cause of sickness before reaching this stage. If bricks, stone, or iron or cement pipe are used for lining wells, and the water in them is frequently renewed by being largely drawn from, it is entirely wholesome and palatable, and is well adapted for nearly all uses, excepting for washing with soap, as before mentioned, and for steam-boilers, in which the large amount of scale deposited from it in evaporation is objectionable.

MATERIAL RESOURCES.

Wheat is the great product of this county, as of the whole Red river valley. Both in yield and quality it here surpasses most other portions of the Northwest. In other directions, however, the agricultural capabilities of this county are great and will some day be more fully developed, as has been indicated in a former part of this chapter, where the soil and timber are described.

Water-powers employed in 1881 were as follows, being three in number, situated on the Buffalo river:

Hawley flouring mills; Craik & Kroll; three-fourths of a mile south of Hawley; head, nine feet; three run of stone.

Buffalo flouring mills; owned by Mrs. Elizabeth Jacobson; leased by William E. Bennett; about two miles south of Hawley; head, also nine feet; two run of stone.

Muskoda flouring mills; Bennett & Pryor; a half mile southwest from Muskoda depot; four run of stone; head, sixteen feet, with canal seven rods long.

Several other water-powers are available on this river; and there are said to be two mill-privileges on the Willow river, one close east of Barnesville, and another about a mile and a half farther east.

Lime has been burned from the magnesian limestone boulders of the drift by Nils Larson, George Hildreth and others, in the southwest part of Eglund and in Parke. The total yearly product is only a few hundred barrels, sold at $1 per barrel. It is mostly white lime of excellent quality, but about a tenth part is yellowish. The limestone boulders are mostly three to five feet long; the largest found had a length of ten feet.

Bricks. A large business in brick-making is done at Moorhead by Lamb Brothers, who began in 1874; Kruegel & Truitt, who began in 1878; and John G. Bergquist and John Early, who began in 1881. Their product in 1881 was as follows: Lamb Brothers, 3,000,000, employing thirty men five months; Kruegel & Truitt, 1,500,000, employing twenty men; Mr. Bergquist, 1,000,000, employing a dozen men; and Mr. Early, 800,000, employing ten men. The black soil is removed to the depth of a foot or one and a half feet; the next one to two feet of the alluvial clay is used for brick-making, its color being dark above and yellowish beneath; the lower continuation of this deposit is unsuited for this use, because of limy concretions. No sand is required for tempering. Sand needed for mortar is brought from Muskoda at the cost of about $3 per cubic yard. The bricks are cream-colored, and of very good quality, selling at about $10 per thousand. Oak wood, used for fuel, costs $5 per cord.

ABORIGINAL EARTHWORKS.

An artificial mound, two or three feet high, is situated on the top of a swell of till some 40 or 50 feet above the upper edge of the delta of the Buffalo river about two-thirds of a mile south of Muskoda depot and one-third of a mile south of the bridge.

Another aboriginal mound, fifty fect in diameter and five feet high, composed of fine gravel though the adjoining surface is boulder-clay or till, is situated in or near the N. W. ¼ of section 22, T. 142, R. 45, about a half mile south of the South branch of the Wild Rice river. It is on land about 60 feet above the east border of the flat plain of the Red river valley in section 16 of this township.

GEOGRAPHICAL AND PERSONAL INDEX.

SCIENTIFIC INDEX.