
ETOILE DU NORD

THE UNIVERSITY OF MINNESOTA.

A REPORT.

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

PUBLISHED BY AUTHORITY OF THE STATE.

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VOLUME VI.


GEOLOGICAL
AND
NATURAL HISTORY SURVEY
OF
MINNESOTA.
N. H. WINCHELL, STATE GEOLOGIST.
Scale: 42 miles to an inch.
KEY TO THE
GEOLOGICAL PLATES.
LAKE OF THE WOODS
RAINY LAKE
LAKE SUPERIOR
KITTSON
ROSEAU
MARSHALL
BELTRAMI
Red Lake and Pembina Indian Reservation
ITASCA
POLK
White Earth Indian Reservation
NORMAN
CLAY
BECKER
HUBBARD
CASS
WADENA
WILKIN
OTTER TAIL
CROW WING
AITKIN
CARLTON
PINE
TODD
MORRISON
MILLE LACS
KANABEC
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
SHERBURNE
ISANTI
CHISAGO
BIG STONE
SWIFT
KANDIYOHI
MEEKER
WRIGHT
ANOKA
HENNEPIN
RAMSEY
WASHINGTON
LAC QUI PARLE
CHIPPEWA
RENVILLE
McLEOD
CARVER
YELLOW MEDICINE
SIBLEY
SCOTT
DAKOTA
LINCOLN
LYON
REDWOOD
NICOLLETT
LE SUEUR
RICE
GOODHUE
WABASHA
BROWN
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
LAKE
COOK
ST. LOUIS
VERMILION
IRON
Hunters Island

1900–1901.

THE

GEOLOGY OF MINNESOTA.

VOL. VI OF THE FINAL REPORT.

GEOLOGICAL ATLAS

WITH

SYNOPTICAL DESCRIPTIONS.

By N. H. WINCHELL.

Submitted October 1, 1900, and published under the direction of the Board of Regents of the University.

COMPRISING EIGHTY-EIGHT GEOGRAPHICAL AND GEOLOGICAL PLATES.

ST. PAUL, MINN.
THE PIONEER PRESS CO., PRINTERS.
1901.

CONTENTS.

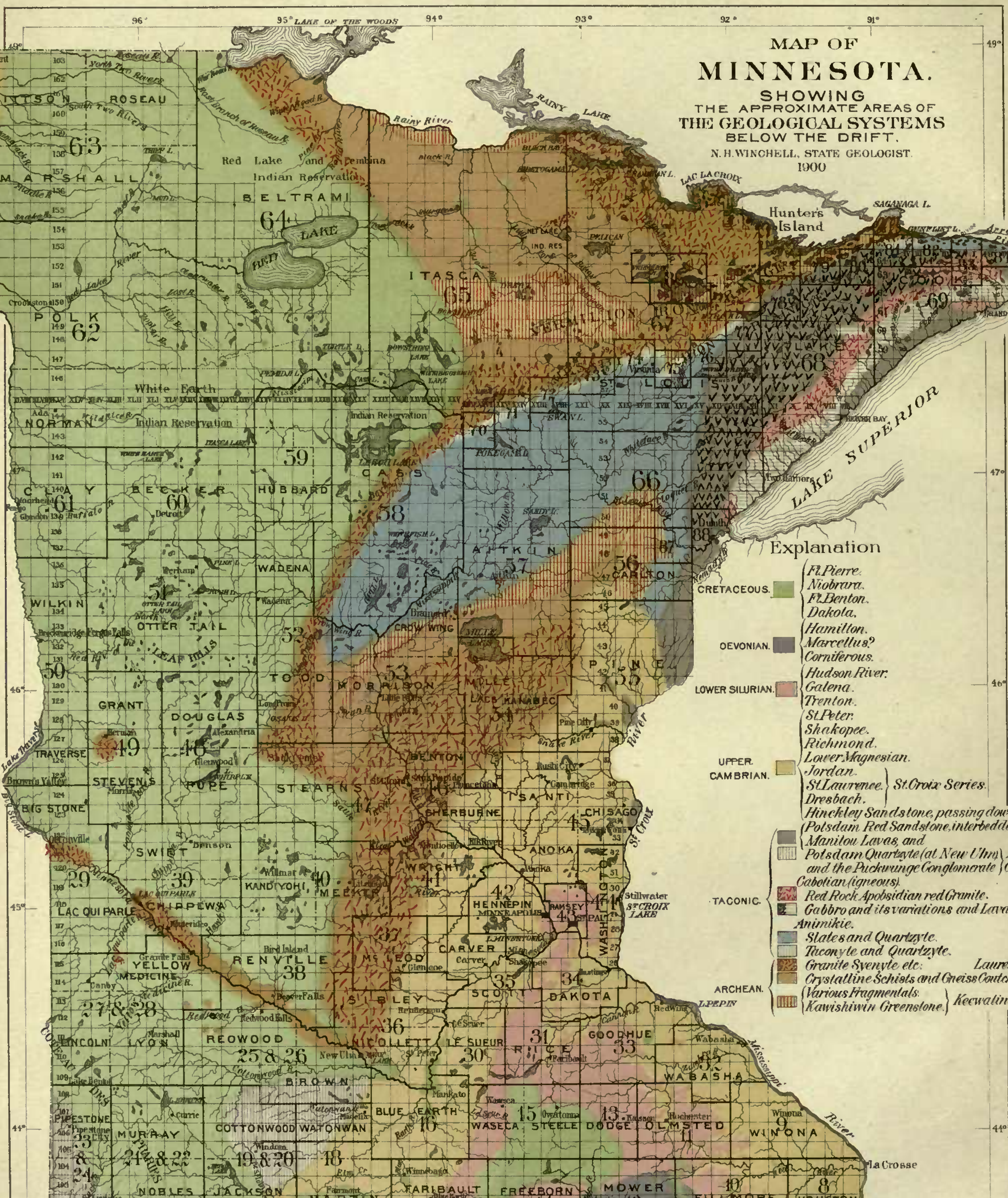
CONTENTS.

PREFACE.

In the main, the brief descriptions that accompany the plates of this atlas are synopses of the chapters of the corresponding plates in the respective volumes of the final report; but not infrequently the reader will find in these descriptions not only new ideas, but also somewhat different conclusions from those of the original chapters. This is because, up to very last, the survey has been also a development of the geology of the state, and occasionally the earlier interpretations need to be modified. There is, however, nothing so discordant with the former chapters as to constitute important departures from the views presented in the volumes containing the detailed descriptions. In most cases attention is called to the fact, when the theoretical part of the synopsis is based on new views.

With these words the writer lays down his pen, after an unceasing labor of twenty-eight years on this enterprise. While the survey, and the report in *tout ensemble*, conform to the conception which he formed when he entered upon the work, yet he is conscious of its numerous defects, and numerous lines of geological research which have not been entered upon. He can, therefore, with strengthened emphasis, repeat the following from the preface of volume I of this report:

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



MAP OF
MINNESOTA.
SHOWING
THE APPROXIMATE AREAS OF
THE GEOLOGICAL SYSTEMS
BELOW THE DRIFT.
N. H. WINCHELL, STATE GEOLOGIST.
1900
Explanation
CRETACEOUS.
Ft. Pierre.
Niobrara.
Ft. Benton.
Dakota.
DEVONIAN.
Hamilton.
Marcellus?
Corniferous.
LOWER SILURIAN.
Hudson River.
Galena.
Trenton.
UPPER CAMBRIAN.
St. Peter.
Shakopee.
Richmond.
Lower Magnesian.
Jordan.
St. Laurence.
Dresbach.
St. Croix Series.
Hinckley Sandstone, passing down into
Potsdam Red Sandstone, interbedded with
Manitou Lavas, and
Potsdam Quartzyte (at New Ulm)
and the Puckwunge Conglomerate
Middle Cambrian.
TACONIC.
Cabotian (igneous).
Red Rock Apobsidian red Granite.
Gabbro and its variations and Lavas.
Lower Cambrian.
Animikie.
Slates and Quartzyte.
Taconyte and Quartzyte.
ARCHEAN.
Granite Syenyte etc.
Laurentian.
Crystalline Schists and Gneiss Coutchiching.
Various Fragmentals.
Kawishiwin Greenstone.
Keewatin.
LAKE SUPERIOR
LAKE OF THE WOODS
RAINY LAKE
Red Lake Indian Reservation
White Earth Indian Reservation

ATLAS.

Geological Map of the State, 1900. N. H. Winchell.

This map is formed by uniting not only the plates, but also the descriptions of the rock formations of the various volumes of the final report. It also contains more than the data that have been published, for it gives an idea of the geological boundaries through some long stretches where, by reason of the heavy drift sheet, the correct location of these boundaries is unknown, but where by a general knowledge of the rocky structure those lines can be shown with an approximation to the truth. Therefore, while it should not be interpreted too closely, it is the final result of the survey, in epitome, as to the geographic limits of the main formations.

A more detailed tabulation of the formations will be found in the preface of volume v. N. H. W.

PLATE I.

HISTORICAL AND GEOGRAPHICAL CHART, 1884. N. H. WINCHELL.

The earliest named geographic feature of Minnesota is lake Superior. It was called *Grand lac* in 1615, by Champlain, which is the translation of the Chippewa name Kitchi Gummi. He, however, did not see that lake, but got his information from the Hurons. By Allouez it was called lake Tracy in 1666, and by Hennepin lake Condé in 1680.

From lake Superior the exploration of the state proceeded westward, the chief factors being the agents of the fur companies, of whom Duluth was one of the most active. There were two routes by which to reach the Sioux who then dwelt at Mille Lacs, one by way of the St. Louis river and thence down the Mississippi to Red Cedar lake, near Aitkin, and the other by way of lake St. Croix (in Wisconsin) and the St. Croix river, and thence by way of the Snake river. These routes were much traveled. But little later the route up the Mississippi to the same Indian settlement was made known (1680) by the narrative of Hennepin, who ascended the Rum river as a captive with the Indians whom he encountered on the Mississippi. Of these earliest explorers, besides Duluth and Hennepin, we have records of Franquelin, Groselliers and Perrot.

The Minnesota river was ascended by LeSueur in 1700 and was mapped by De L'Isle in 1703. The international boundary was first mapped by an Indian (Otchagach) in 1730, and Lake of the Woods by Verendrye in 1731. The mythical river Long was ascended by La Hontan in 1689. The interior of the state was known later. Gen. Z. Pike in 1805 explored the Mississippi valley as far as to Cass lake, and Morrison wintered at Itasca lake in 1804. Joseph Nicolas Nicollet, however, was the chief pioneer in exploring and mapping the interior portion of the state. This was in 1841. He was aided by Gen. J. C. Fremont. See Plate VII. Major S. H. Long was at the falls of St. Anthony in 1817, and again in 1823. Gov. Lewis Cass made an expedition in 1820 to the upper waters of the Mississippi. Mr. H. R. Schoolcraft accompanied him, and also returned in 1832, when, in company with Lieut. James Allen, he claims to have discovered and named Itasca lake. It appears to have been known before.

The student of early exploration in Minnesota will find the publications of these explorers in the library of the Minnesota Historical Society at St. Paul. N. H. W.

NOTE. The name Hohang, on the authority of Featherstonhaugh, may be applied to the St. Croix river, 1835; and the name Clearwater river, near Wapashaw, should be transferred to the next river farther north.

PLATE 1.

Julius Bien & Co. lith.

PLATE II.

PART OF FRANQUELIN'S MAP OF NORTH AMERICA, 1688.

This plate, with the exception of the rude map by Hennepin, Plates V and VI, shows the earliest known map of the territory now included within the state of Minnesota. This is a portion of the map of Franquelin, made in 1688 for King Louis XIV. It is from a tracing obtained by the late E. D. Neill from a map in the *Archives des Mines*, at Paris. Were the natural features represented on this map properly adjusted geographically, it would be found to extend from the northern boundary of the state to the mouth of the Ohio river.

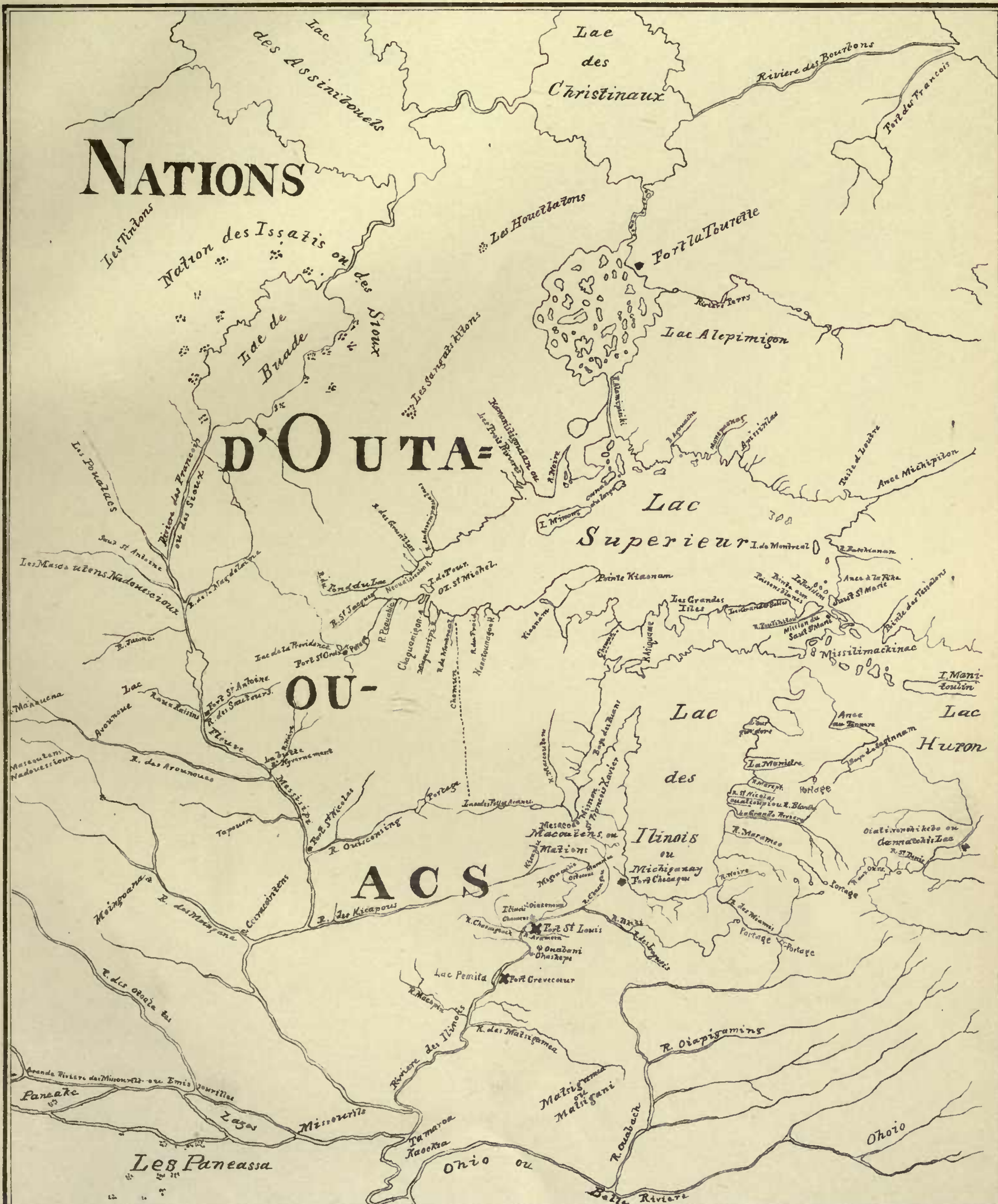
Lac Buade is Mille Lacs, and lakes Assinibouils and Christinaux are on the international boundary. Lac Alepimigon is lake Nipigon. Rivière des François (Rum) is represented as the principal course of the Mississippi, the outlet of lac Buade. The Mississippi was evidently unknown above the mouth of the Rum river. It is designated "Les Poualacs," indicating that it is the route to the Indian tribe known by that name (see Plate I). This map also shows approximately the position of the falls of St. Anthony (Sault St. Antoine), proving that Hennepin's map had been seen, or that Hennepin's narrative had been read, by Franquelin. Méssisipi is the name here given to the Mississippi. About the same time, but a little earlier, Hennepin had called it St. Louis river, and La Salle Colbert river. The river named "des Arounouacs" is probably meant for the Root river, which then passed through the region of the Iowas. The river "Jaune" is the Vermilion river below Hastings. The St. Croix river is named "de la Magdelaine." Of the streams entering lake Superior from Minnesota, the Pigeon river is called "R. Grossillers." The St. Louis is called "R. du Fond du Lac," and the Nemadji is named "St. Jacques." It is interesting to note that here is also a river called "Peouabic," or Iron river, indicating that the iron range of Wisconsin had already been discovered as early as 1688. It is the first river east of the Bois Brulé river.

Lake Pepin is represented, but not named. Fort St. Antoine is shown at the mouth of the river "des Sauteurs," *i. e.*, the Chippewa river, and "la butte d'hyvernement" at the mouth of Black river. The R. aux Raisins is probably the Zumbro river. The Minnesota river is called "des Mascoutens Nadouscioux," *i. e.*, the river of the Mascoutens, a well known tribe of the Sioux Indians who remained in that part of Minnesota until removed by government after the outbreak of 1862.

N. H. W.

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

PLATE 2



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

J. Bien & Co Photo lith

PLATE IV.

BUACHE'S CARTE PHYSIQUE, 1754.

This physiographic map is intended to show, in the terms of its title, "the most elevated lands of the western part of Canada, in which are seen the new discoveries of the French officers west of lake Superior, with the rivers and lakes of which M. Jeremie speaks in the Hudson Bay report." It was constructed by Buache about 1754. In this, as in other early maps, Mille Lacs is confounded with Red lake under the double designation, "Rouge ou Missisagaigan," and from it flow streams, one going to the northwest under the name, "R. Rouge ou Mescouesipi," reaching lake Bourbon (Winnipeg), and the other toward the south, which, though unnamed, can be no other than Rum river, as it reaches the Mississippi above the mouth of the St. Croix river. The source of the "R. St. Pierre," or the Minnesota river, is represented to be in the lake of the Tintons (Big Stone lake), *i. e.*, in the region of the Tintonwan, a Sioux tribe long resident on the upper waters of the Minnesota. "R. du Fond du Lac" is the St. Louis river, and the "Nalouagan" is the Pigeon river. Fort Frances is here called "Fort St. Pierre." Rainy lake is called "Lac Tecamemiouon ou de la Pluie." Lake of the Woods is called "L. Minouiltacou ou des Bois." The "Moingona" river is now the Des Moines. The "Rivière de l'Ouest," entering the "Mer de l'Ouest," with the village "Quivera" at its mouth, were evidently intended to represent the limit of geographical knowledge in that direction. "Quivera" was thus on the Pacific coast, the long mountain range being the Rocky mountains. N. H. W.

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

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

PLATES (PAGES) V AND VI.

HENNEPIN'S MAP OF NEW FRANCE, 1683.

The map of Hennepin, 1683, by which lake Buade, or lake Mille Lacs, is represented as northwestward from lake Superior instead of southwestward, is probably responsible for the same error in Franquelin's map (Plate II), made in 1688 and in others. Yet in his narrative Hennepin describes this lake as situated "about seventy leagues west of lake Condé." The Mississippi river is conjecturally represented by a dotted line as flowing into the gulf of Mexico. The Illinois river is named Seignelay; the Wisconsin is called Oisconsins; above that is the river Noire, or Black river; the next above, on the east, is river des Bœufs; the St. Croix is styled R. du Tombeau, and between it and Rum river, which is denominated the St. Francis, is a water connection of lakes and streams. There is one river above the St. Francis, but unnamed. The Mississippi is represented as having no tributaries from the west, and as flowing between two ranges of mountains from the falls of St. St. Anthony to some distance below the Wisconsin. These mountains are simply the rock-bluffs of the river valley consisting of horizontal strata cut by the river itself. Lake Pepin is named "Lac des Pleurs;" Mille Lacs is Lac Buade, name given by Duluth; lake Superior is Condé ou Superior.

The coat of arms of France (fleur de lis), probably as established by Duluth, is represented at the most northwesterly point on the map, surmounted by a figure of the cross, and beneath it are inscribed these words:

Armes du Roy telle
quelle sont Grauée
sur l'escorce d'un
Chesne ă l'endroit
marqué—A.

The point indicated by A is at the west shore of lake Buade, and probably indicates the place (Kathio) where Hennepin was held in captivity, and the location of the Indians at that time.

North from lake Buade are represented lakes and streams, with missions of the Recollects, the order to which Hennepin belonged. Les Hanctons, or later the Ihanktonwan, Indians are represented as residing beside some waters to the north of lake Buade, and still further north are the Changaskobé ou Nation des Forts, which probably refers to the Chippewas, who then dominated lake Superior. Toward the west further is the Lac des Assenipoils, or Poualak, and to the northeast from lake Buade are the Oua de Battons ou gens de Rivière.

Reduced for the Geologica


MTRION
330
340
350
360
10
20
30
60
50
40
30
20
10
10
NOUVELLE
BRETAGNE
I. de Terre Neuve
I. Percée
Grand Banc.
IRLANDE
ANGLETERRE
La Manche
PARTIE DE FRANCE
PARTIE D'ESPAGNE
I. Azores
MER DE CANADA
LE TRIOMPHE DE LA LOUISIANE
I. Canaries
Partie d'AFRIQUE
ORIENT
ue du Cancer
Isles Antilles Françoises
QUE
IONALE
CARTE DE LA NOUVELLE FRANCE ET DE LA LOUISIANE
Nouvellement decouverte
dediée
Au Roy
l'an 1683.
Par le Reuerend Pere
Louis Hennepin
Missionaire Recollect
et Notaire Apostolique
N. Guerard
310
320
330
340
350
360

The course of the Mississippi proper, above the Rum river, is probably indicated by an insignificant unnamed stream (mentioned above), while the main stream is continued northwestwardly to a village of Indians named Tinthonka ou gens des Prairies, afterward known as the Tintonwan, who had their village at Big Stone lake at the head of the Minnesota river. It is apparent, therefore, that Hennepin, who did not visit that region, had but a confused idea of the relation of the Minnesota with the Mississippi, and no conception of the importance of the Mississippi above the mouth of Rum river.

N. H. W.

PLATE VII.

NICOLLET'S MAP, 1842.

Nicollet's map of the upper Mississippi, the Minnesota, the Red River of the North and the James River valleys constitutes the most important contribution ever made to the topography and physical geography of Minnesota.* He incorporated all facts previously known, and added much to their number and their exactness, in constructing the map, a part of which is reduced and shown by Plate VII. He gave names to many lakes and physical features or adopted those which were current. Catlin, Schoolcraft, Featherstonhaugh, Allen, Keating and Long had preceded him, but they were mainly confined to the ready routes of travel, passing through the country in a single season, but Nicollet crossed the country in all directions and spent several years, winters included, in procuring the data of his map.

Within Minnesota are represented two remarkable physical characters, *i.e.*, two districts of lakes. One of these, the Undine region, includes the great bend of the Minnesota river at Mankato, running from Dakota county southwestward to Brown county and then northwestward, its western area, under the name Plateau du Coteau des Prairies, extending through several counties to the head of that range in Dakota, westward from Traverse lake. The other tract covers the upper waters of the Mississippi, its lakes and its numerous streams, these constituting the perennial source, or Victoria Nyanza, of the Mississippi and of the Red river of the North. Connecting these is a range of low hills named Coteau du Grand Bois, later known as the Big Woods, the last name, however, being latterly extended to include the whole timbered spur which projects as far south as to the southern limit of the Undine region and divides the original prairies of the state into eastern and western portions.

Lake Buade, called also Missisagaigan on some French maps, meaning many, or much, lake, and translated by the early French by Mille Lacs, by the time of Nicollet had lost entirely the name given it by Hennepin, and is Minsi sagaiagoning, or Mille Lacs. Its outlet, called river St. Francis by Hennepin, is by Nicollet called Iskodo Waboo, or Rum river, *i. e.*, Skootay Waboo, or Fire-Water, river, indicating that the present name of that river was of Chippewa origin, and has simply been translated into English.

The geographical names of Nicollet's map have mostly been perpetuated to the present time. It is just to the early explorers that the first names applied to lakes and streams be preserved, whenever they are known, and especially when they are attested by the publication of a good map or description. N. H. W.

* Joseph Nicolas Nicollet, the Minnesota geographer, should not be confounded with Jean Nicollet, who was an American pioneer from France nearly 200 years earlier, but who never visited Minnesota. See *American Geologist*, vol. viii, pp. 343-352, 1891, and vol. xiii, pp. 126-128, 1894. Also *Wisconsin Historical Collections*, vol. xi, pp. 1-22.

NICOLLET'S UPPER MISSISSIPPI_1842.

Reduced for the Geological and Natural History Survey of Minnesota

Julius Bien & Co. lith.

PLATE VIII.

HOUSTON COUNTY, 1884. N. H. WINCHELL.

Of all the southern counties this is the most hilly. It was channelled by numerous water courses, and also suffered a general surface degradation, prior to the spreading of the loam, and probably prior to the Cretaceous, *i. e.*, in the long interval between the Lower Silurian and the Cretaceous, while the county and the surrounding country in Minnesota, Wisconsin and Iowa was probably a land surface. The present rough surface is due to the excavation of channels by streams during that long interval. How much of the eastern part of the county was originally covered by the Lower Silurian can only be conjectured, but it seems to have been all covered by a uniform stratum, or series, which was continuous with similar rocks on the east side of the Mississippi in Wisconsin.

The Mississippi and Root rivers are somewhat over 500 feet below the bluffs, and all the smaller streams run in similar rock-bound gorges. The Root River valley is about two miles in width between the bluffs, and the horizontal strata through which the valley has been excavated present frequent outcrops in the form of precipitous cliffs and crags. Away from the valleys the country is simply undulating and sometimes spreads out in extended plateaus on which are large and flourishing farms.

The most elevated portion is about Spring Grove (1194 feet), where the elevation is 574 feet above the Mississippi river at the southern line of the county.

The soil of the upland country is generally rich, being made of the loess-loam, both surface and subsoil. This loam is thicker and more clayey toward the Mississippi, and occasionally becomes sandy in the western portion of the county. The only place in the county at which a foreign drift was observed is at Riceford, where a scanty foreign gravel was seen in the valley of Rice creek. A terrace largely composed of similar materials is scantily exposed along the Mississippi. It can be seen at La Crescent rising about 50 feet above the Mississippi flood plain. The lands in the valleys are of alluvium, but sometimes are quite sandy.

The rocks consist of alternating magnesian limestones and quartz sandstones belonging to the Upper Cambrian, and of blue limestones and shales of the Lower Silurian, the latter overlying the former and appearing in Wilmington and Spring Grove townships. The bluffs of the Mississippi and Root rivers, and of nearly all their tributaries, are sharpened along their crests by the Lower Magnesian limestone, which is about 200 feet thick.* Above this stratum, but usually not well exposed,

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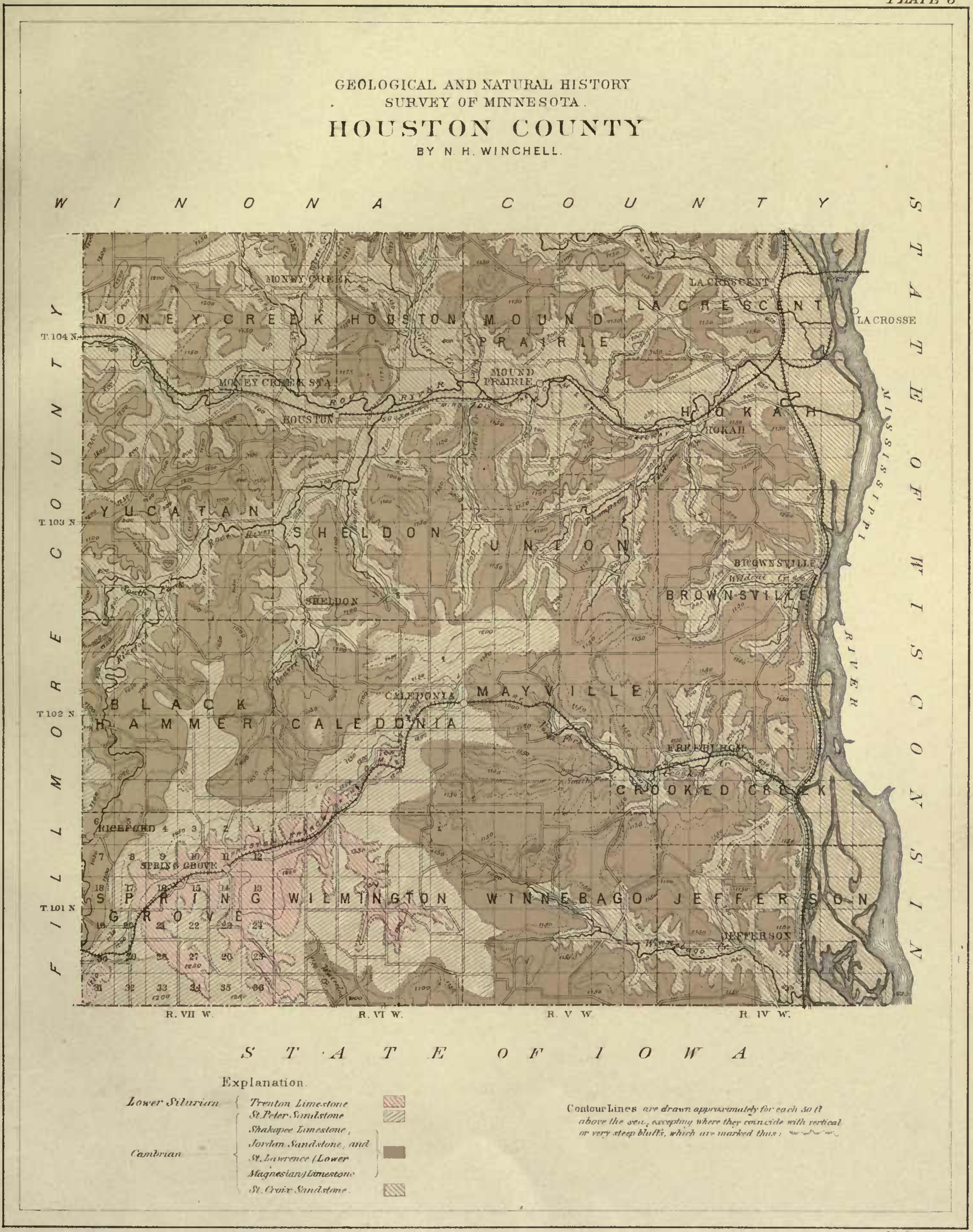
*This was wrongly called St. Lawrence limestone in volume i. The correction was made in the preface of volume ii.



Julius Bien & Co. lith.

are the Jordan sandstone and the Shakopee limestone. These occur under the loam of the upland, but rarely appear in the main bluffs. Below the Lower Magnesian limestone is sandstone (St. Croix). In the midst of this are a great amount of shale and a small amount of limestone. The last, which has been quarried at Hokah, is the St. Lawrence limestone proper. This sandstone and shale continue to the river level.

N. H. W.

PLATE IX.

WINONA COUNTY, 1884. N. H. WINCHELL.

With respect to the Mississippi river and the tributary drainage and consequent channelling of the original rock surface, this county presents the same features as Houston county, but in the northern and western portions these features are slightly modified by a scant deposit of northern drift, which fades out imperceptibly under the loam. Besides this fringe of the glacial deposit along the west there is a notable amount of northern drift in the Mississippi valley. This appears in the protected angles of the bluffs, and is apparently closely connected in date and origin with a gravelly terrace which also is conspicuous in numerous places in the tributary valleys. It seems probable that a long tongue of the glacier descended the Mississippi gorge as in a fjord, obstructing all the tributary streams, leaving a scant morainic deposit along the bluffs, remains of which can be seen at Winona. Such spur from the northern ice would also cause the terracing of the lateral streams. This terrace is seen in many of the larger valleys, constituting the principal feature of their topography. The upper portion of this terrace is frequently a loam undistinguishable from the loam of the upland, but the lower portion consists of coarser sand, and often of gravel. This terrace is about fifty feet above the flood plain adjacent.

The general surface is covered everywhere by a clayey loam, which gives the county its fine soil and agricultural capabilities. This loam becomes sandy at points where a copious supply of sand could be obtained from the St. Peter, Jordan or St. Croix sandstones.

The highest part of the county is south of St. Charles, where the Trenton hills rise to 1,325 feet above the sea, the depot at St. Charles being 1,131 feet and situated about at the top of the Shakopee limestone. The uplands along the Mississippi are about 1,200 feet above the sea, but the crest of the limestone outcrop is about 1,100 feet. The Mississippi descends, between the north county boundary and the southern, from 650 feet to 627 feet above the sea.

The county has many copious springs of clear cold water, and as the streams are largely maintained by these the brook trout is found in some of them.

Important quarries are at Winona, in the Lower Magnesian limestone; also at Stockton. Excellent brick are made at several places, especially at Dresbach.

N. H. W.

PLATE 9.

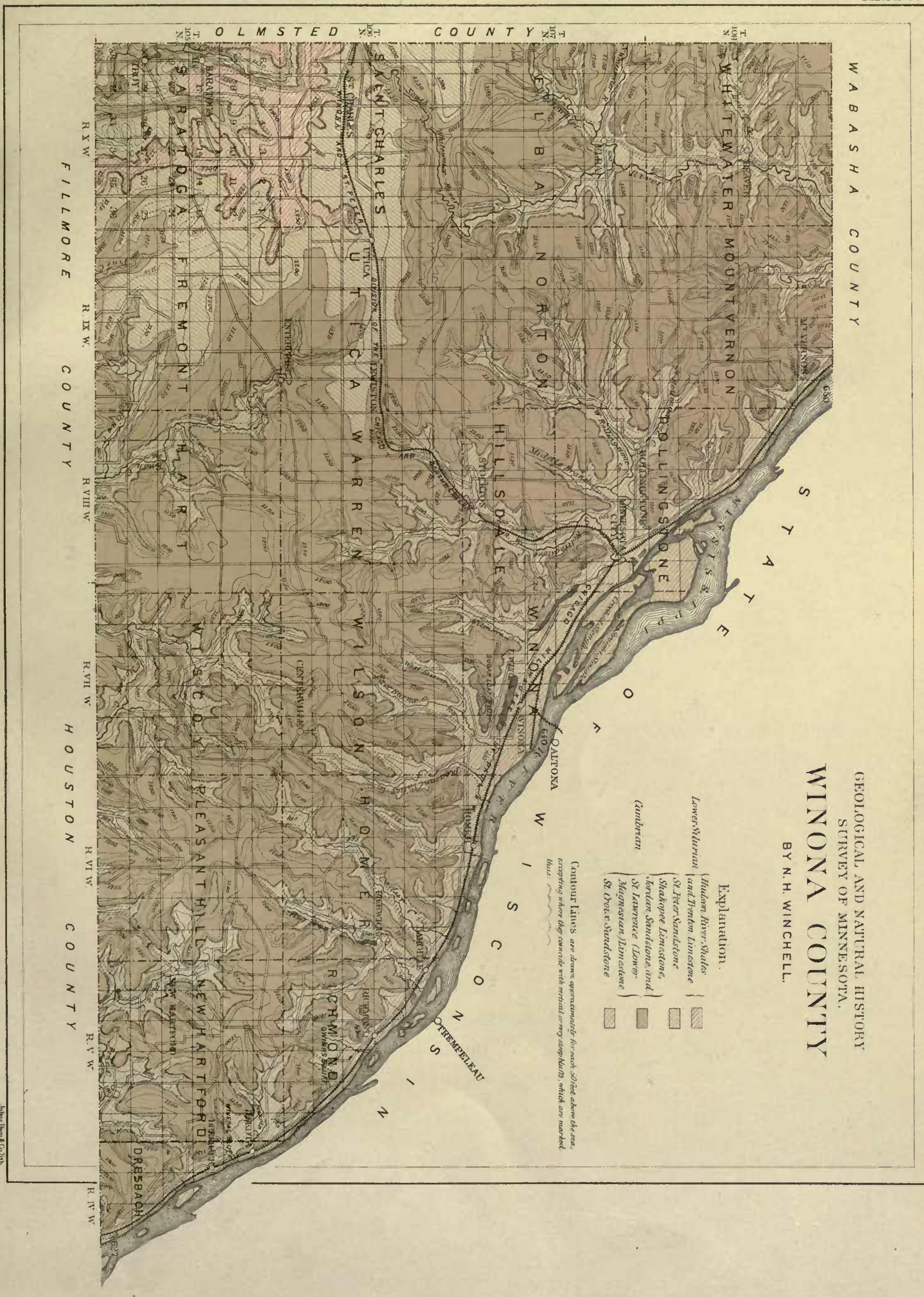

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
WINONA COUNTY
BY N. H. WINCHELL.
Explanation.
Lower Silurian
Hudson River Shales and Trenton Limestone
St. Peter Sandstone
Shakopee Limestone, Jordan Sandstone, and St. Lawrence (Lower Magnesian) Limestone
Cambrian
St. Croix Sandstone
Contour lines are drawn approximately for each 50 feet above the sea, excepting where they coincide with vertical or very steep bluffs, which are marked thus:
WABASHA COUNTY
OLMSTED COUNTY
FILLMORE COUNTY
HOUSTON COUNTY
STATE OF WISCONSIN
MISSISSIPPI RIVER
WHITEWATER
MOUNT VERNON
ELBA
NORTON
ROLLINGSTONE
SAINT CHARLES
UTICA
WARREN
HILLSDALE
WINONA
SARATOGA
FREMONT
HART
WILSON
HOMER
RICHMOND
WISCOY
PLEASANT HILL
NEW HARTFORD
DRESBACH
TREMPELEAU
ALTOONA
R.X.W.
R.IX.W.
R.VIII.W.
R.VII.W.
R.VI.W.
R.V.W.
R.IV.W.

PLATE X.

Fillmore County, 1884. N. H. Winchell.

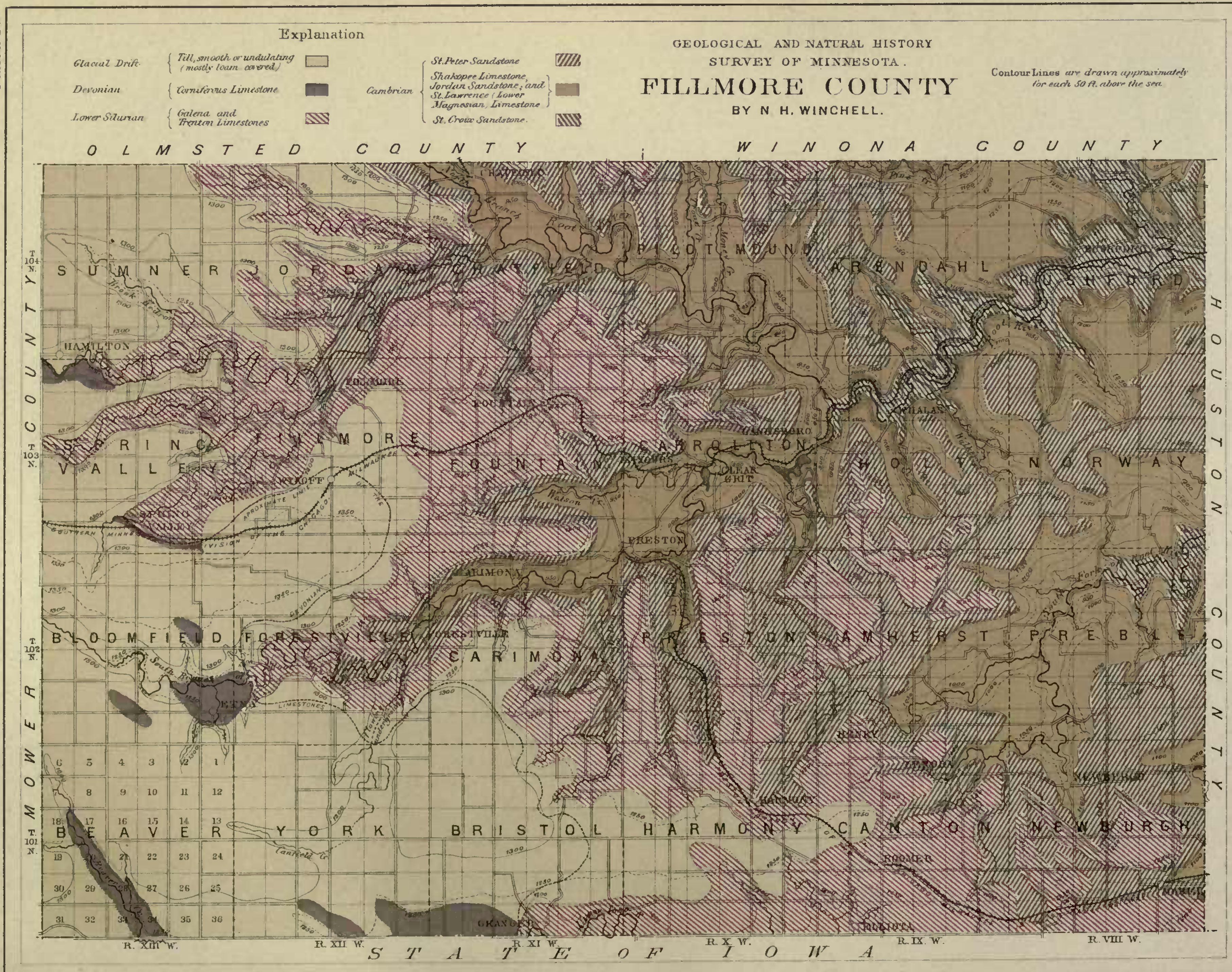
The rolling character of surface which prevails in Houston and Winona counties becomes ameliorated and finally disappears entirely in Fillmore county. The south-western one-third portion of this county is characterized by extensive and uniform prairies. The general surface is everywhere a loam which seems to be the continuation of that of counties further east, but it becomes more and more affected toward the west by the underlying sheet of northern drift, and that drift also appears more and more abundantly exposed in all excavations that penetrate the loam, and along the valleys of the streams.

Root river, with its fan-like tributaries, drains nearly the whole county, descending from an average level of about 1,300 feet at the west to about 700 feet at the northeast. At the west it runs on a drift-and-loam surface, with no rock exposure. At the northeast it meanders through a wide, rock-bound, alluvial valley over two miles wide, which lies 565 feet below the tops of the bluffs. It descends over the strike of the Lower Devonian, the Silurian and about 375 feet into the St. Croix sandstones and shales. The Upper Silurian is in some places, as at Spring Valley, shut out by an overlap of the Devonian upon the Lower Silurian. Unconformably overlying all the Paleozoic rocks is a little Cretaceous, which exists in the western part of the county, probably belonging to the Dakota and the Fort Benton groups.

The drift has been found to consist, along the west side of the county, of two layers of till, separated by a bed of peat, the upper till being sometimes nearly fifty feet thick. The peat contains branches of trees, apparently of cedar. At Preston, besides the flood plain the river has a high terrace plain consisting of loess-loam, undistinguishable from the loam that covers that portion of the county. This appears also at Lanesboro and at Whalen, while at Rushford it only exists in fragmentary remnants seen in the valleys of the tributary streams. There are two terrace levels besides the flood plain. The highest terrace plain at Rushford is from seventy to eighty feet above the second, and about 130 feet above the river.

In Fillmore county formerly was made a large quantity of quicklime from the Galena (Trenton) limestone. The county is well supplied with fuel by the native forest, and, having a good soil of varied capabilities and a diversified surface, it ranks amongst the first in its agricultural attractions.

Spring Valley, and the railroad cuts eastward from Spring Valley, and the bluffs about Wykoff and Chatfield, are favorable fossil localities. N. H. W.



Julius Bien & Co. lith.

PLATE XI.

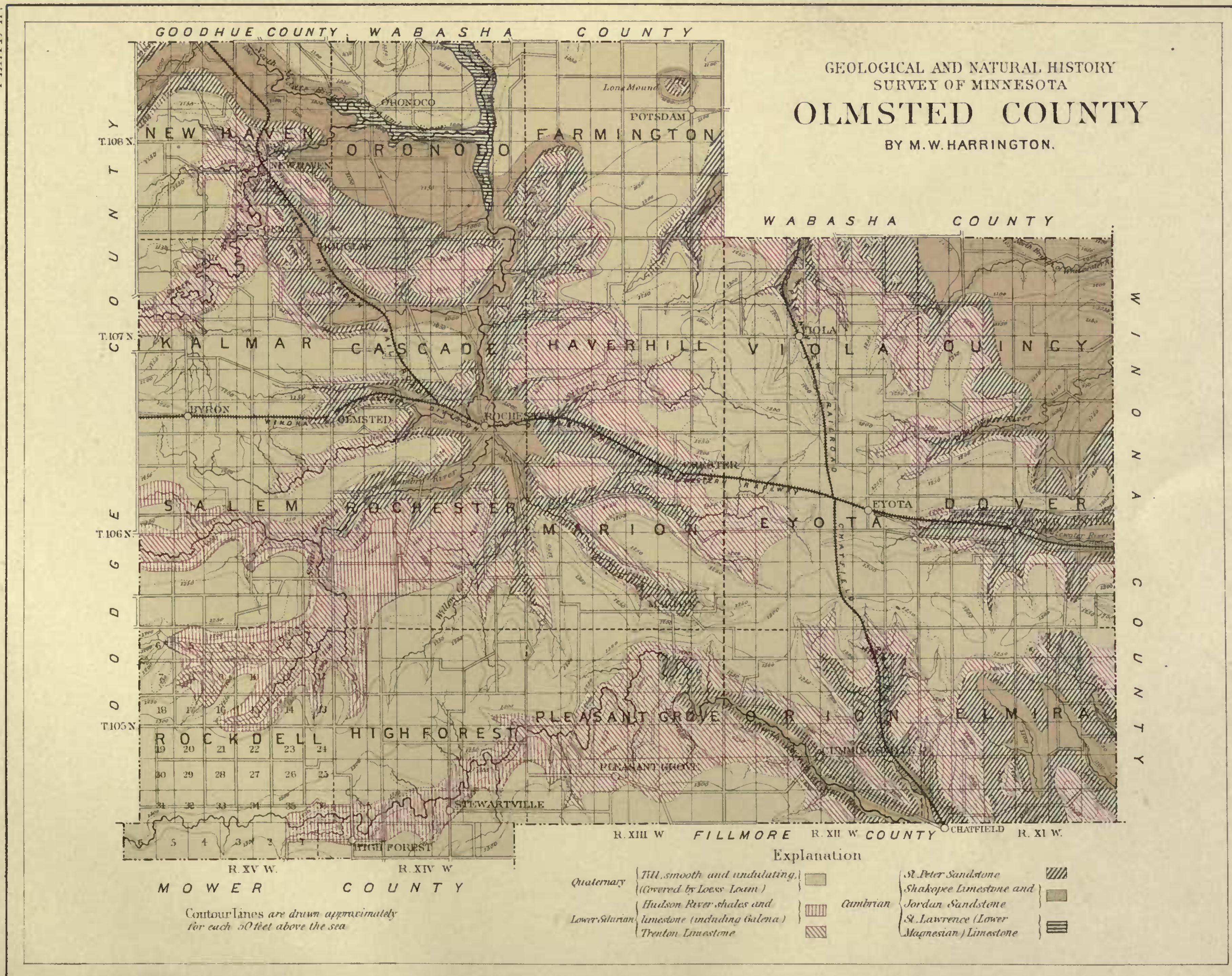
OLMSTED COUNTY, 1884. M. W. HARRINGTON.

This county is quite similar to Fillmore in topography and all general features. It has wide rocky valleys whose bluffs, however, are generally so rounded over by drift and loam that they are not so precipitous as in Fillmore and Winona counties. In general, further, the rocks at the surface are of the Silurian rather than of the Upper Cambrian, and they therefore do not have that series of alternating sandstones and limestones which facilitates the cutting of wide gorges by the rivers. In the area of the Silurian, therefore, the gorges are inclined, in the absence of drift, to become sharp and deep, but as they are largely drift-filled, they do not reveal themselves until the drift and loam are re-excavated. Such old valleys are disclosed sometimes by "sink-holes" which are formed by the collapsing of the loam, and which become more frequent and larger in the direction toward the gorge of some creek tributary to some of the larger streams.

The towns of Rock Dell and High Forest are the most elevated of the county, averaging about 1275 feet above sea—mainly of prairie, while Orinoco and Cascade are the lowest, being about 1075 feet above sea level, and more timbered. Originally Olmsted county was well timbered. It has a characteristically loamy soil, but this becomes sandy along the outcropping line of the St. Peter sandstone. There are no lakes in the county, but numerous springs of pure cool water. These are by far the most numerous on the south and west sides of bluffs where the natural dip of the green clay of the Trenton causes the underground water to come to the surface as springs, forming the "spring row" which characterizes many of the elevated plateaus formed of the Trenton and the St. Peter.

As in Winona, Fillmore and Houston counties, Olmstead county is furnished with numerous small water powers at which feed-and flour making machinery is kept in motion sufficient for the local demand, and at some of the larger water powers extensive mills furnish flour for an extensive export.

Many fossils have been collected from the Trenton in the vicinity of Rochester and at Chatfield, and along the river at Stewartville. N. H. W.



Julius Bien & Co. lith

PLATE XII.

MOWER COUNTY, 1884. N. H. WINCHELL.

The prairies, which begin to be continuous in the western part of Fillmore county, extend westward through Mower county, interrupted only by narrow fringes of trees which accompany the streams. The valley of the Upper Iowa river at Le Roy, and those of Bear and Deer creeks, are of the nature of the pre-glacial valleys mentioned in connection with counties further east, but they are insignificant in comparison with them. The valley of Cedar river, south from Austin, also exhibits somewhat the same gorge-like pre-glacial character. In general, however, this county affords a broad, moderately undulating expanse of elevated prairie, the basis of which is glacial drift with a good loam-like soil.

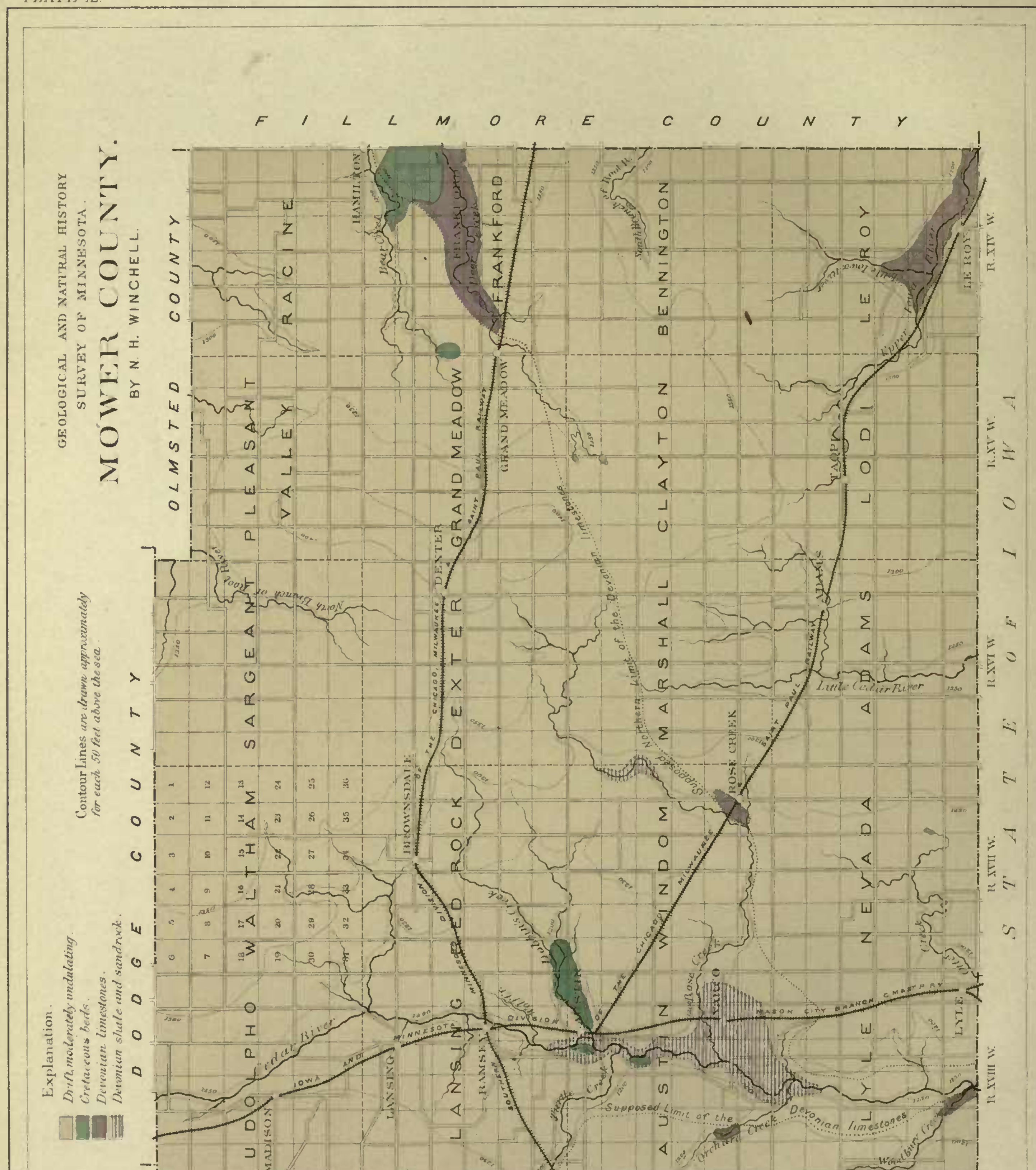
The highest point in the county is about a mile east of Dexter, 1,412 feet, and the lowest is at the exit of the Cedar river, at the southwest corner of the county, probably about 1,100 feet.

Although the Devonian occurs at several places in this county, and is supposed to underlie a large part of it—probably the southern half—yet this formation in Minnesota is not well known. It should have further study before any positive conclusions as to its extent and nature can be given.

Patches of Cretaceous have been discovered, as represented on the map, and some fossil Cretaceous leaves have been described from Austin. These beds are of clay and sandstone, the former frequently kaolinic, the result of local decay and leaching of the older formations, followed by wash and redeposition by the Cretaceous ocean. It is very probable that the Cretaceous underlies the drift extensively throughout the county, and contributes largely to the general evenness of the surface.

In the southern part of this county, at several points, a peaty vegetable layer is known, lying between two till sheets. N. H. W.

PLATE 12.



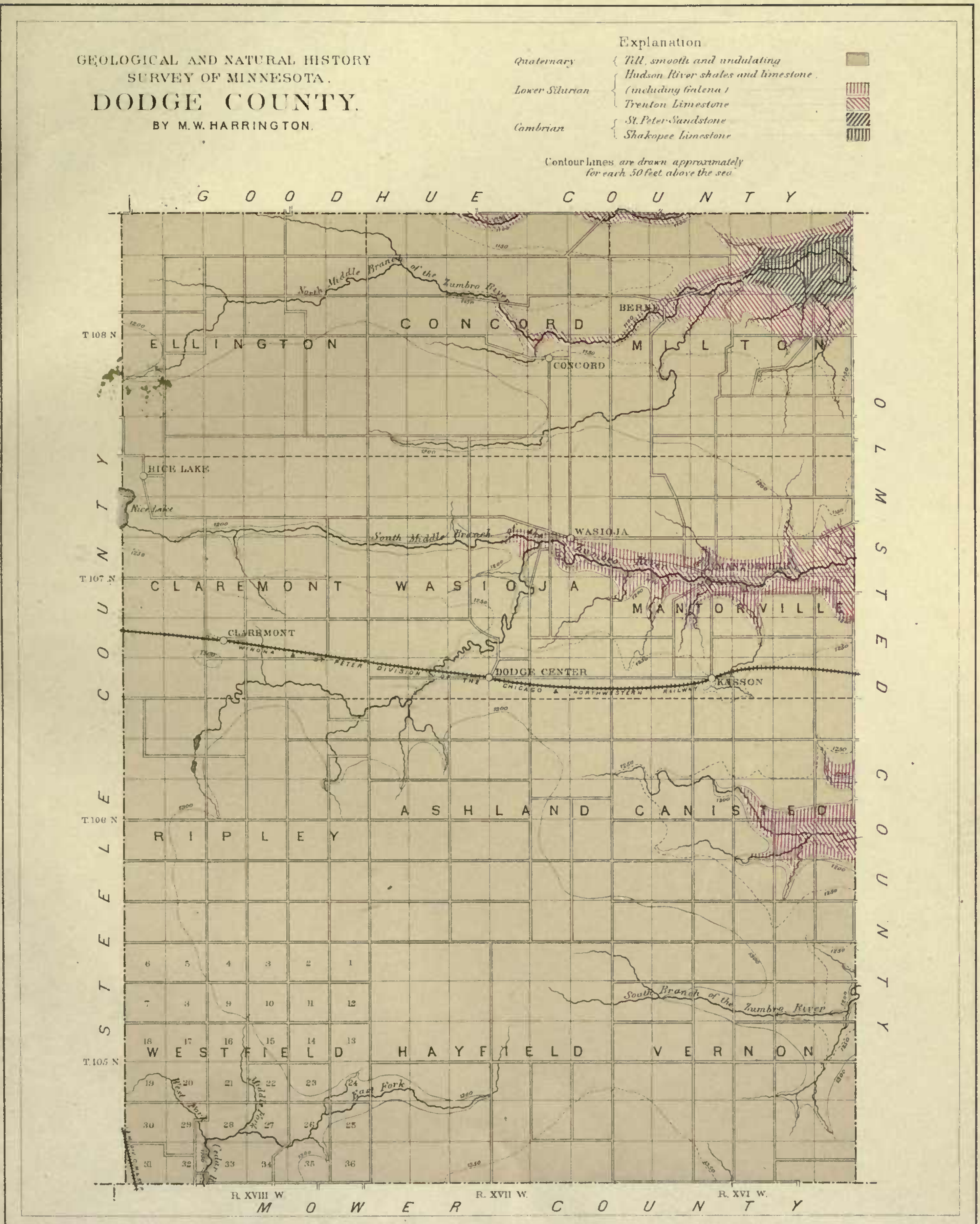
Julius Bien & Co. lith.

PLATE XIII.

DODGE COUNTY, 1884. M. W. HARRINGTON.

The valleys in the northeastern part of Dodge county, cut in the Lower Silurian, are the westward vanishing extension of those of Olmsted county. The rest of the county is a uniform and nearly flat prairie where the streams wander about on the surface of the drift, having excavated but insignificant depressions, and occasionally expand into swampy lakelets. The highest parts of this prairie are south of Dodge Centre, something over 1,300 feet. The lowest points in the county are in the valley of the Middle Branch of the Zumbro, about 1,000 feet. On the highland prairies, especially along the shallow basins occupied by the small streams and lagoons, are frequent large granite boulders, sometimes twenty-five or thirty feet long, constituting a marked natural exception to the prevailing monotony. These are not confined to this county, but are met with also in Mower and many other counties. They attest the former activity of some powerful transporting agency from the northern and central parts of the state, the nature and relative date of which, amongst the varied drift forces, have not yet been sufficiently elucidated. The drift consists essentially of a tenacious blue clay with stones, probably largely augmented by debris from the Cretaceous, but toward the northeast this blue clay seems to fade into a yellow loam.

The Trenton limestone (or Galena) is quarried at Mantorville, and red brick are made at Dodge Centre and Kasson. The county is a typical one of the upland prairies of the southern part of the state. N. H. W.



Julius Bien & Co. lith.

PLATE XIV.

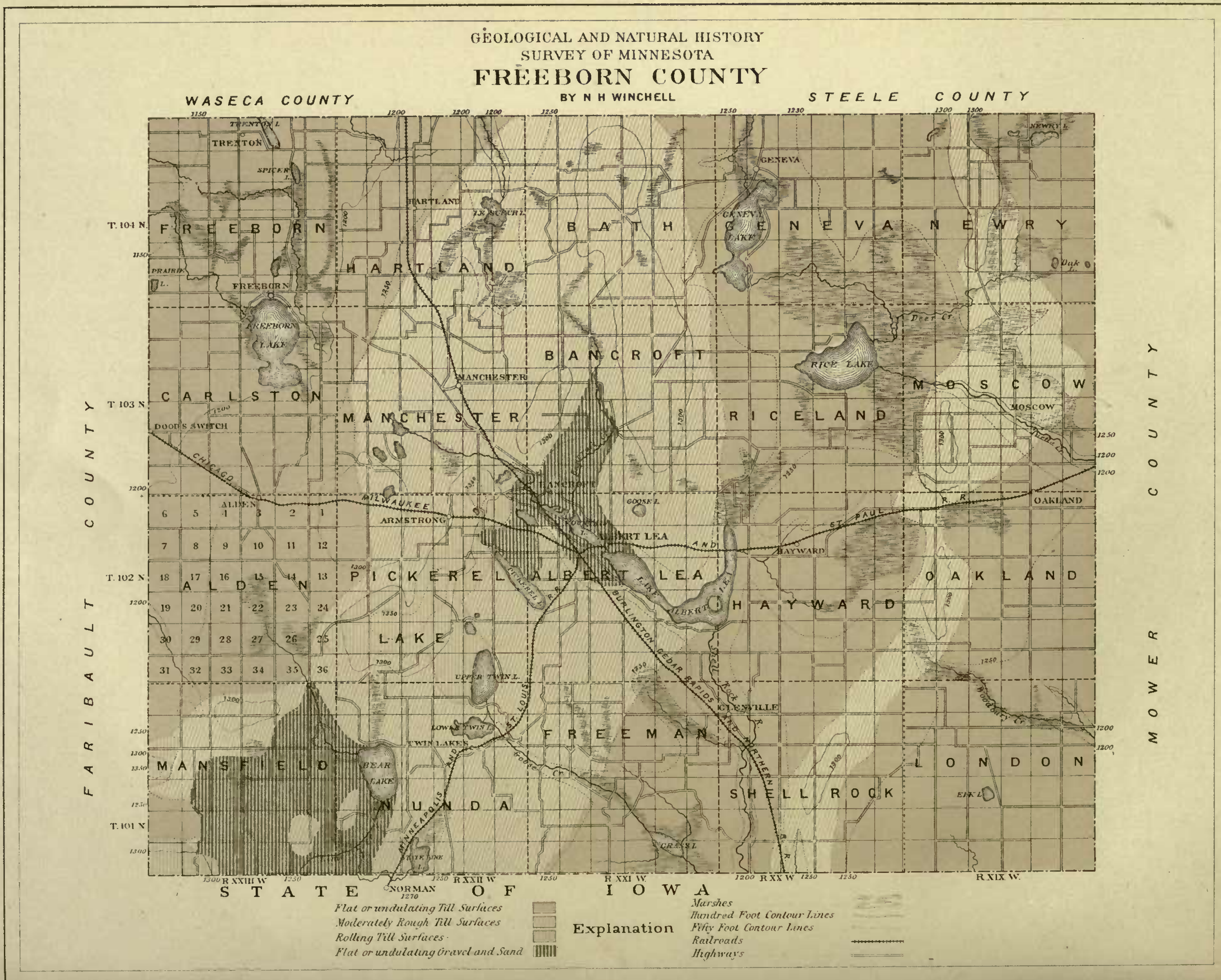
FREEBORN COUNTY, 1884. N. H. WINCHELL.

There is not a rock outcrop in Freeborn county. The surface is flat or gently undulating, but rises to hilly in small areas. These hilly areas are parts of two belts which cross the county from north to south, characterized by somewhat more rolling surface than the prairies on either side. The most rough tracts are in section 16, in Newry township, and in sections 1 and 2, in Pickerel Lake township, the hills rising from 50 to 100 feet above the adjacent surface. In general the whole county is one of prairie, but scattering oak openings are found, while oak shrubs are common about the shores of some of the lakes and along the streams.

The streams are small and sluggish, running through marshy tracts, but afford water-power at Albert Lea and at Twin Lakes. The county has several fine lakes, but their margins are apt to be marshy. Those in the morainic belts are exempt from such marshes, and are generally deeper. In the western morainic belt are two extensive sand plains, viz., Paradise prairie, north from Albert Lea, and the plain known as Bear Lake prairie, in the southeastern part of Marshfield.

Nothing is known directly as to the geological structure. It is inferred from the known geology of some adjoining counties, and from the abundance of limestone boulders throughout the most of the county, which were formerly much more frequent, that the Devonian limestone underlies much of the county below the drift and the Cretaceous. The deep wells drilled at Albert Lea for artesian water passed mainly through a magnesian limestone, whose lithological characters were not diagnostic of the Devonian seen at Le Roy, in Mower county, but may appertain to the Trenton (Galena) of the Lower Silurian. (Compare the Fourteenth Annual Report, page 348.) This limestone, with its variations to shale and sand, has a thickness of 186 feet. The discharge of water in one of the Albert Lea wells was about 400 barrels per day; but in the other, which started at a higher level, water stands at twenty-two feet below the surface. In the latter rock was struck at the depth of 114 feet. Other deep wells have since been sunk at Albert Lea, and they seem to indicate that the Devonian lies nonconformably upon the Upper Silurian at a depth of about 275 feet beneath the city. Several wells with artesian flow have been obtained at Albert Lea.

The well sunk at Freeborn, in search for gas, went to the depth of 950 feet, and its record was interpreted as follows: Drift, 150 feet; Galena limestone, 10 feet; Trenton limestone and shales, 310 feet; St. Peter sandstone, 180 feet; Lower Magnesian (with its parts, Shakopee, Richmond and main body of limestone) and Jordan


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
FREEBORN COUNTY
BY N H WINCHELL
WASECA COUNTY
STEELE COUNTY
FARIBAULT COUNTY
MOWER COUNTY
STATE OF IOWA
FREEBORN
HARTLAND
BATH
GENEVA
NEWRY
BANCROFT
CARLSTON
MANCHESTER
RICELAND
MOSCOW
ALDEN
PICKEREL
ALBERT LEA
OAKLAND
HAYWARD
LAKE
FREEMAN
MANSFIELD
NUNDA
SHELL ROCK
LONDON
TRENTON
GENEVA
HARTLAND
FREEBORN
FREEBORN LAKE
RICE LAKE
MANCHESTER
MOSCOW
DODD'S SWITCH
ALDEN
ARMSTRONG
BANCROFT
ALBERT LEA
HAYWARD
OAKLAND
GLENVILLE
TWIN LAKES
NORMAN
BEAR LAKE
UPPER TWIN L.
PICKEREL L.
ALBERT LEA L.
CHICAGO MILWAUKEE AND ST. PAUL R.R.
BURLINGTON CEDAR RAPIDS AND NORTHERN R.R.
MINNEAPOLIS AND ST. LOUIS R.R.
T. 104 N.
T. 103 N.
T. 102 N.
T. 101 N.
R. XXIII W.
R. XXII W.
R. XXI W.
R. XX W.
R. XIX W.
Explanation
Flat or undulating Till Surfaces
Moderately Rough Till Surfaces
Rolling Till Surfaces
Flat or undulating Gravel and Sand
Marshes
Hundred Foot Contour Lines
Fifty Foot Contour Lines
Railroads
Highways

sandstone, 250 feet; St. Lawrence limestone (with the accompanying shales) pierced 50 feet; total 950 feet. The small quantities of gas found in the vicinity of Freeborn are supposed to be derived primarily from the vegetable layer embraced in the drift, which is known at several places in this and other counties. The coal that was sought by shafting at Freeborn in 1873 and 1874 was Cretaceous lignite. N. H. W.

PLATE XV.

STEELE COUNTY, 1884, M. W. HARRINGTON, AND WASECA COUNTY, 1884.
WARREN UPHAM.

Steele County.

This county continues the features of Freeborn county toward the north, with a gradual slope toward the north. The Straight river, at about two miles north of Owatonna, first encounters bedrock. This belongs to the Trenton. The surface, except for the bluffs that accompany the streams and the moderate, rolling morainic belts that cross the county, is essentially a flat prairie, but originally had considerable small timber and brush. One of these rolling belts extends north and south across the eastern part of the county, varying from a mile and a half to six miles in width. The other belt skirts along the western edge of the county, partly lying in Waseca county, and has an average width of about six miles. The tract between these belts is drained by the Straight river and its tributaries, as in Freeborn county, most of its ultimate sources being in lakes and springs located amongst the morainic hills. These streams frequently meander through swampy tracts before they unite in Straight river.

The highest portion of the county is in the rolling tract in Blooming Prairie, near the Freeborn county line, at about 1,350 feet above tide, and Straight river leaves it with an elevation of about 1,050 feet.

There is a belt of larger timber from two to four miles in width accompanying Straight river, especially in the northern part of the county.

The deep well drilled at Owatonna in 1878 had a depth of 387 feet, and passed ninety-seven feet into the St. Peter sandstone without having an artesian overflow. Under the drift, having a thickness of thirty-four feet, was found a white sandstone fifty-nine feet in thickness, belonging io the Cretaceous. N. H. W.

Waseca County,

Having a morainic belt along its eastern border, but which turns toward the northwest through Woodville, Blooming Grove and Iosco, spreads out westwardly in a tract of monotonous, nearly level, prairie. Some streams, however, diversify this prairie, flowing westward to the Minnesota river. Along these streams more or less timber is found. Finally, toward the northwest, the surface is very largely timbered. The most uniformly flat prairie region is found in Byron, Vivian, Freedom and Wilton townships, which were probably covered by a glacial lake during a part of the retreat of ice-sheet (see Blue Earth and Faribault counties). The valley of the Le Sueur river is broad and shallow, not exceeding forty feet, and usually less than


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
STEELE COUNTY
BY M. W. HARRINGTON.
WASECA COUNTY
BY WARREN UPHAM.
Explanation
Glacial Drift
Till, undulating or nearly flat
Till, rolling, or hilly; Terminal Moraines.
Hudson River limestone and shale.
Contour Lines are shown approximately for each 50 ft. above the sea
Note. The glacial drift is shown by wells to be underlain at several places by Cretaceous beds, which perhaps occupy a large part of these counties, but probably have no great thickness, and lie upon Lower Silurian formations
LE SUEUR COUNTY
RICE COUNTY
DODGE COUNTY
FREEBORN COUNTY
FARIBAULT CO.
BLUE EARTH COUNTY
WASECA
STEELE
JANESVILLE
IOSCO
BLOOMING GROVE
DEERFIELD
MEDFORD
CLINTON FALLS
MERTON
ALTON
ST MARY
WOODVILLE
MERIDEN
OWATONNA
HAVANA
FREEDOM
WILTON
OTISCO
LEMOND
SOMERSET
AURORA
VIVIAN
BYRON
NEW RICHLAND
BERLIN
SUMMIT
BLOOMING PRAIRIE
Eastern or Outer Terminal Moraine
Western or Inner Terminal Moraine
CHICAGO & NORTHWESTERN R.Y.
WINONA & ST PETER
MINNEAPOLIS & ST LOUIS
MINNESOTA DIV. OF THE CHICAGO MILWAUKEE & ST PAUL
T 108
T 107
T 106
T 105
R XXIV W
R XXIII W
R XXII W
R XXI W
R XX W
R XIX W

twenty-five feet below the adjoining county. This valley, and all others, are cut in the drift, without exposing any bedrock.

The highest part of Waseca county is New Richland and in the southeast part of Otisco, about 1,200 feet above the sea. Its lowest point is in the Le Sueur valley, where that stream crosses the western county line, about 1,010 feet.

At New Richland several wells reached a white sandstone, which may be either Cretaceous or St. Peter, but is presumed, on general considerations, to be the former.

N. H. W.

PLATE XVI.

Blue Earth County, 1884. Warren Upham.

A large part of this county, probably five-sixths of it, was originally prairie, and very flat, due, apparently, to the prevalence of a glacial lake during the later part of the ice retreat, by which the drift sheet was smoothed and washed off, filling the depressions with a lacustrine clay. Yet this county contains a large supply of timber. This prevails in the northeastern quarter of the county, where it is well known as the "big woods," and along the numerous streams that converge in the Undine region to unite with the Minnesota river at Mankato, of which the Blue Earth is the main trunk, the spreading forks being known from the west as the Minneopa, Watonwan, Perch, Willow, Blue Earth, Maple, Big Cobb, Little Cobb, Le Sueur and Iosco. This general and remarkable descent toward Mankato serves to render that locality a favorable one for artesian wells, of which there are several.

Since the spreading of the drift and the lacustrine clay the surface drainage has served to reopen some of the pre-glacial (and pre-Cretaceous) gorges, and hence the present streams, beginning on the surface of the drift deposits and running on it without much excavation for many miles, at length find some of these old rock-cut valleys, and pursue these gorges till they reach the Minnesota river, which itself runs in a similar pre-glacial gorge from Minneopa northward. Southward from Mankato are to be found numerous such gorges, partially uncovered, not now occupied by streams, which once were portions of the drainage system of the region. The county has many lakes, situated on the upland drift surface. There are two small rolling tracts approaching the characters of a moraine, but which may be due to locally copious waters acting on the drift in the process of deposition, due to the disturbing effect of prominent irregularities in the underlying rocky surface. These are in the northwest part of Sterling and the southeast part of Pleasant Mound. There is also a wide, more undulating belt extending northwestward from lake Jackson through Vernon Center and Garden City.

The valley of the Minnesota is from 200 to 225 feet below the general surface, and that of the Blue Earth and its tributaries is about the same toward the north, but toward the south it is much less.

The rocks of the county belong to the Upper Cambrian and to the Cretaceous. The former furnish good building stone and quicklime and cement at Mankato, while the latter contain much kaolinic clay, a residual product of rock decay in pre-Cretaceous time. Below the Upper Cambrian the deep wells at Mankato entered a great thickness of red sandstone and unctuous red shales, belonging to the later Keweenawan or early Potsdam age, although without trap. This red formation, which here


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
BLUE EARTH COUNTY
BY WARREN UPHAM.
Contour Lines are drawn approximately for each 50 feet above the sea. Cretaceous Beds overlying the Lower Magnesian are not represented.
Explanation.
Recent Alluvium.
Modified Drift High Terrace of Sand and Gravel.
Kames
Glacial Drift Till, flat or undulating.
Lower Mag. Shakopee Limestone.
Jordan Sandstone
St. Lawrence Limestone.
NICOLLET COUNTY
MINNESOTA RIVER
LE SUEUR COUNTY
WASECA COUNTY
BROWN COUNTY
WATONWAN COUNTY
MARTIN R. XXIX W. COUNTY
R. XXVIII W. FARIBAULT R. XXVII W. COUNTY R. XXVI W.
R. XXV W.
T. 109 N.
T. 108 N.
T. 107 N.
T. 106 N.
T. 105 N.
CAMBRIA
BUTTERNUT VALLEY
JUDSON
LIME
JAMESTOWN
MANKATO
LE RAY
SOUTH BEND
LINCOLN
GARDEN CITY
RAPIDAN
DECORIA
Mc PHERSON
CERESCO
VERNON CENTER
LYRA
BEAUFORD
MEDO
PLEASANT MOUND
SHELBY
STERLING
MAPLETON
DANVILLE
MARYSBURG
MANKATO JUNCTION
EAGLE LAKE
Tivoli P.O.
Park P.O.
Judson P.O.
ICELAND STA.
LAKE CRYSTAL
GARDEN CITY
Watonwan P.O.
Decoria P.O.
Belleview P.O.
Beauford P.O.
GOOD THUNDER
Medo P.O.
Porch Lake P.O.
EDGEWOOD
Myrna P.O.
VERNON CENTER
MAPLETON
Danville P.O.
Sherman P.O.
Willow Creek P.O.
Champion Mills P.O.
AMBOY
Sterling Center
SHELBYVILLE
Pleasant Mounds P.O.
Winnebago Agency P.O.
HILTON
RAPIDAN Quarry
MINNESOTA
SIOUX CITY DIV. OF CHICAGO
CHICAGO & NORTHWESTERN RY.
WINONA & ST. PETER
MANKATO & WELLS BRANCH
BLUE EARTH CITY DIV. OF
LOON L.
EAGLE LAKE
MADISON L.
DUCK L.
L. WASHINGTON
L. GEORGE
SOLBERG L.
LAKE JACKSON
RICE LAKE
INDIAN L.
L. ALICE
Maple River
Big Cobb River
Le Sueur River
Little Cobb R.
Watonwan R.
Perch Cr.
Willow Cr.
Blue Earth R.

developed a thickness of 1,300 feet, and extended lower, is found widely in central Minnesota. It is apparently the chief formation in which was done the pre-Cretaceous excavation of the valleys and gorges of Blue Earth county, where they extend much below the present water level.

Blue Earth county possesses varied resources and ranks amongst the first in the state.

N. H. W.

PLATE XVII.

FARIBAULT COUNTY, 1884. WARREN UPHAM.

This is another of those prairie counties within the limits of which there is not a single natural outcrop of the underlying rocks, and it does not present many exceptional features requiring mention.

Its flat or undulating surface is broken by two areas of more rolling or morainic character, one of which is a spur from the southwest corner of Freeborn county, running northwestward nearly across Faribault county, having an average width of about two and a half miles, the most marked part of which is the Kiester hills in Kiester township, which rise from 100 feet to 200 feet above the lowlands, the highest points being about 1,400 feet above the sea. The other rolling tract is in Pilot Grove and Elmore townships, and extends into Iowa and westwardly into Martin county. It is more subdued in contour, the hills rising from forty to sixty feet.

Faribault county shared in the glacial lake that covered parts of Blue Earth county. The level of this lake was approximately 1,150 feet above the sea, and its depth, in the north part of Faribault county, was 50 to 125 feet; on the west line of Waseca county about 75 feet, and in the north part of Blue Earth county about 200 feet. The lake was of comparatively short duration and had its outlet by way of the Des Moines river, through the "big slough," in Kossuth county, Iowa. The valley connecting the Des Moines with the most southern branch of the Blue Earth river resembles that connecting the valley of the Red River of the North with the Minnesota valley, through which was the outlet of lake Agassiz.

Timber of large and dense growth usually occupies the bottom lands and bluffs of Blue Earth river, and of its east fork to a distance of fifteen miles above its mouth. It also forms groves or narrow belts on the borders of nearly all the lakes and creeks.

The county has numerous artesian fountains in the vicinity of Wells. These are from 110 to 120 feet deep, and the water, which is of excellent quality, rises from five to fifteen feet above the surface. The source or head of this water is supposed to be in the morainic elevated land in Freeborn county lying northward from Albert Lea. The water seems to be confined by the till sheet, and to be contained in a porous sandstone, the upper portion of which is strongly cemented by iron rust. Other similar artesian fountains are obtained from gravel and sand beds in the glacial till at varying depths. They are frequent in Dunbar, Minnesota Lake and Lura, extending into Mapleton and Sterling, in Blue Earth county. They are also in Emerald and in Pilot Grove.

This is strictly an agricultural county, but possesses many natural elements that, like Blue Earth county, allow a wide range of agricultural industry. N. H. W.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
FARIBAULT COUNTY.
BY WARREN UPHAM.
Explanation.
Modified Drift. Kames.
Glacial Drift. Till, flat or undulating.
Morainic Till, rolling.
Morainic Till, roughly hilly.
Contour Lines are drawn approximately for each 50 feet above the sea.
BLUE EARTH COUNTY
WASECA COUNTY
FREEBORN COUNTY
MARTIN COUNTY
STATE OF IOWA
T. 104 N.
T. 103 N.
T. 102 N.
T. 101 N.
R. XXVIII W.
R. XXVII W.
R. XXVI W.
R. XXV W.
R. XXIV W.
WINNEBAGO CITY
DELAVAN
LURA
MINNESOTA LAKE
DUNBAR
VERONA
PRESCOTT
BARBER
WALNUT LAKE
CLARK
JO DAVIESS
BLUE EARTH CITY
EMERALD
BRUSH CREEK
FOSTER
PILOT GROVE
ELMORE
ROME
SEELY
KIESTER
LURA L.
BASS L.
MINNESOTA LAKE
EASTON
DELAVAN
WINNEBAGO CITY
WELLS
HUNTLEY
SWAN L.
Barber P.O.
OLAHTANKA LAKE
WALNUT LAKE
GOOSE L.
Banks P.O.
RICE L.
SWAN L.
Brush Creek P.O.
Emerald P.O.
Ewald P.O.
Clayton P.O.
Kiester Hills
GORMANS L.
BLUE EARTH CITY
Pilot Grove P.O.
ELMORE
MANKATO BRANCH
SOUTHERN MINNESOTA DIV. OF C. M. & ST. P. RY.
CITY DIV. OF C. ST. P. M. & O. RY.
Julius Bien & Co. lith.

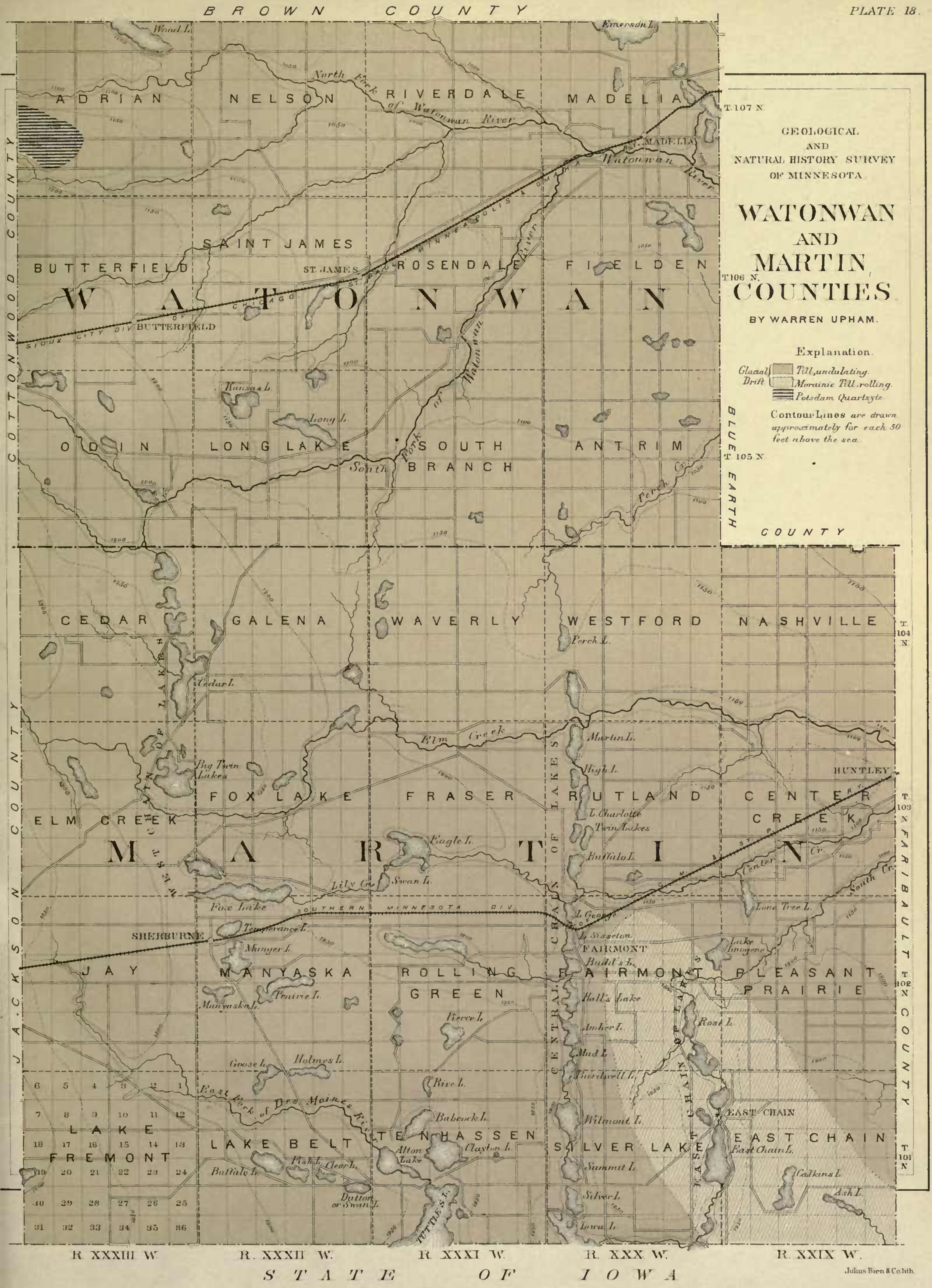
PLATE XVIII.

WATONWAN AND MARTIN COUNTIES, 1884. WARREN UPHAM.

These counties are characterized by an undulating expanse of till, in which the streams and lakes lie but fifteen to forty feet below the surface. They do not much differ from Faribault county and from the southern part of Blue Earth. Martin county has no rock outcrop, although Cretaceous debris is so common that it is quite probable that that formation underlies most of the county. The Potsdam quartzyte appears in the township of Adrian, in the northwestern corner of Watonwan county, causing an abrupt and prominent ridge that rises from 50 to 100 feet above the adjoining surface. This is a part of the same ridge that extends westward about twenty-two miles into Cottonwood county. The rock is hard, distinctly bedded, and frequently of a red color. Its surface is glaciated in the direction S. 30° E., true meridian, and S. 20° E. Aside from this quartzyte ridge it is probable that the drift of Watonwan county is immediately underlain by the Cretaceous.

A tract of country, somewhat more rolling than the rest, enters Martin county at the southeast corner and extends nearly to Fairmont, having a width of about five miles. This, however, does not present a strong contrast with much of the central part of Martin county, and it may not be of morainic origin.

The remarkable series of "chains of lakes" in Martin county are thought to owe their origin and location to old valleys excavated in interglacial time in the drift of the first glacial advance. These old valleys served as drainage courses to supply the Des Moines river and mark the converging streams that united to excavate the channel of that river at points further south. They were partly filled by the drift deposited by the second glacial epoch, but were not obliterated. It is probable that they are largely excavated in that member of the Cretaceous which Dr. C. A. White named the Nishnabotany sandstone. N. H. W.


GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
WATONWAN AND MARTIN COUNTIES
BY WARREN UPHAM.
Explanation.
Glacial Drift
Till, undulating.
Morainic Till, rolling.
Potsdam Quartzyte.
Contour Lines are drawn approximately for each 50 feet above the sea.
BROWN COUNTY
COTTONWOOD COUNTY
JACKSON COUNTY
BLUE EARTH COUNTY
FARIBAULT COUNTY
STATE OF IOWA
WATONWAN
MARTIN
ADRIAN
NELSON
RIVERDALE
MADELIA
BUTTERFIELD
SAINT JAMES
ROSENDALE
FIELDEN
ODIN
LONG LAKE
SOUTH BRANCH
ANTRIM
CEDAR
GALENA
WAVERLY
WESTFORD
NASHVILLE
ELM CREEK
FOX LAKE
FRASER
RUTLAND
CENTER CREEK
JAY
MANYASKA
ROLLING GREEN
FAIRMONT
PLEASANT PRAIRIE
LAKE FREMONT
LAKE BELT
TENHASSEN
SILVER LAKE
EAST CHAIN
ST. JAMES
MADELIA
FAIRMONT
SHERBURNE
HUNTLEY
EAST CHAIN
T. 107 N.
T. 106 N.
T. 105 N.
T. 104 N.
T. 103 N.
T. 102 N.
T. 101 N.
R. XXXIII W.
R. XXXII W.
R. XXXI W.
R. XXX W.
R. XXIX W.
North Fork of Watonwan River
Watonwan River
South Fork of Watonwan River
East Fork of Des Moines River
Elm Creek
Lily Cr.
Center Cr.
South Cr.
Perch Cr.
CHICAGO ST. PAUL MINNEAPOLIS & OMAHA
SIOUX CITY DIV.
SOUTHERN MINNESOTA DIV.
CENTRAL CHAIN OF LAKES
EAST CHAIN OF LAKES
Wood L.
Emerson L.
Kansas L.
Long L.
Perch L.
Cedar L.
Big Twin Lakes
Fox Lake
Temperance L.
Manyaska L.
Eagle L.
Swan L.
Martin L.
High L.
L. Charlotte
Twin Lakes
Buffalo L.
L. George
L. Sisseton
Budd's L.
Hall's Lake
Amber L.
Mud L.
Lone Tree L.
Lake Imogene
Rose L.
Prairie L.
Pierce L.
Holmes L.
Goose L.
Rice L.
Babcock L.
Alton Lake
Clayton L.
Wilmont L.
Summit L.
Silver L.
Iowa L.
East Chain L.
Calkins L.
Ash L.
Dutton or Swan L.
Julius Bien & Co. lith.

PLATES (PAGES) XIX AND XX.

COTTONWOOD AND JACKSON COUNTIES, 1884. WARREN UPHAM.

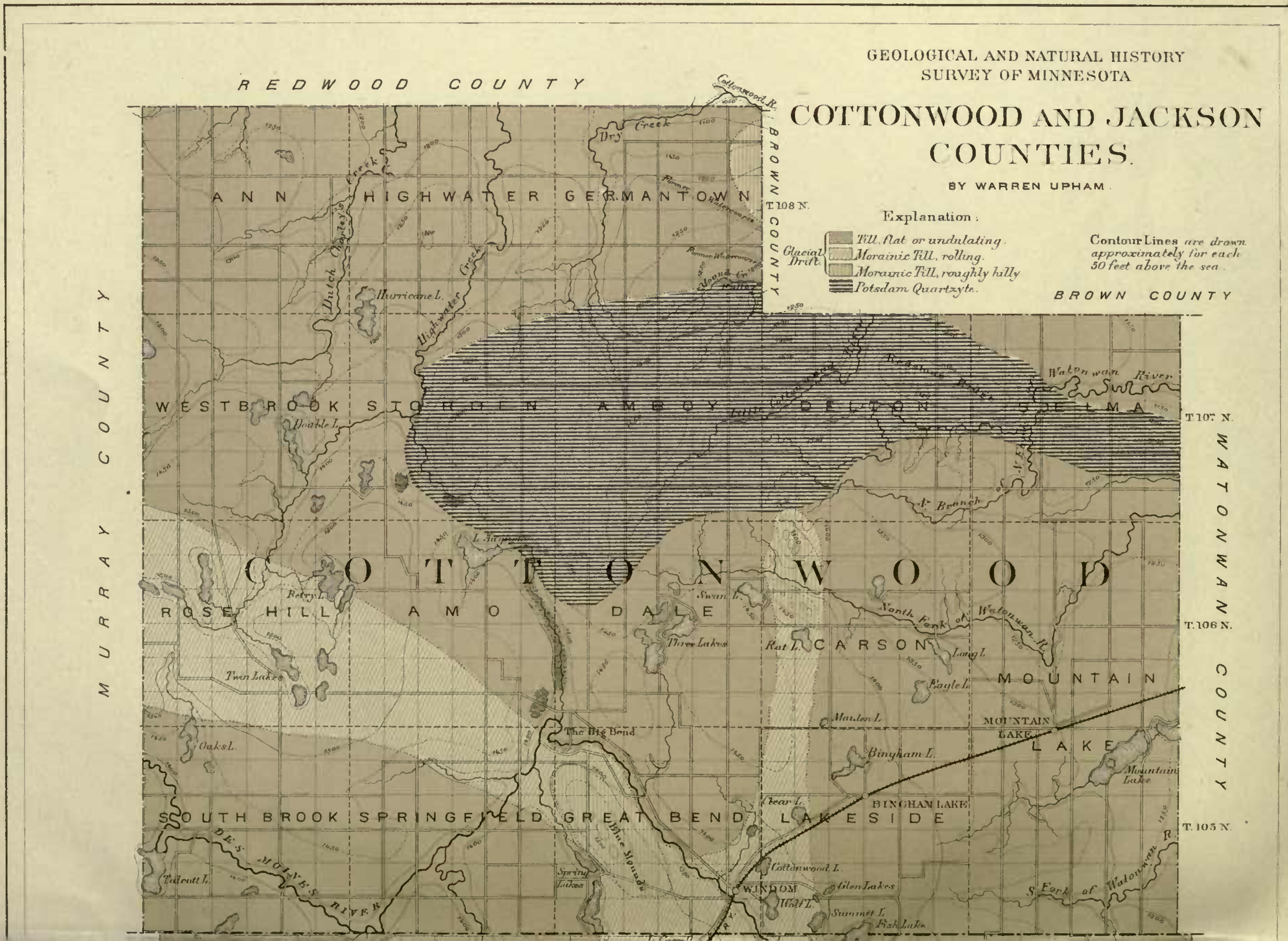
Extending from Watonwan county westwardly into Cottonwood county is a prominent plateau caused by the Potsdam quartzyte. It runs to the western part of Storden a distance of about twenty-two miles in this county, where it disappears gradually by flattening out and running below the drift. The width of this ridge, as a known quartzyte range, varies from two to seven miles. Structurally it is a monocline, with a dip toward the south, becoming nearly horizontal toward the west. The rock is hard and very refractory, but, judging from the use that is made of the same rock at Sioux Falls, it could be put to extensive use in construction if it were treated systematically and thoroughly. At the exposed surfaces it is much broken by jointage, and it also carries small beds of catlinyte, like that at Pipestone. Some of the sedimentary layers are massive, reaching two feet in thickness. As a whole this rock might be considered the southerly arm of the anticline which shows its northern arm at Redstone, near New Ulm. This formation probably extends much further south, under the drift. The ridge rises on the north side rather abruptly, about 100 feet at the east end and 300 feet at the west, the full hight reaching 1,500 feet above the sea.

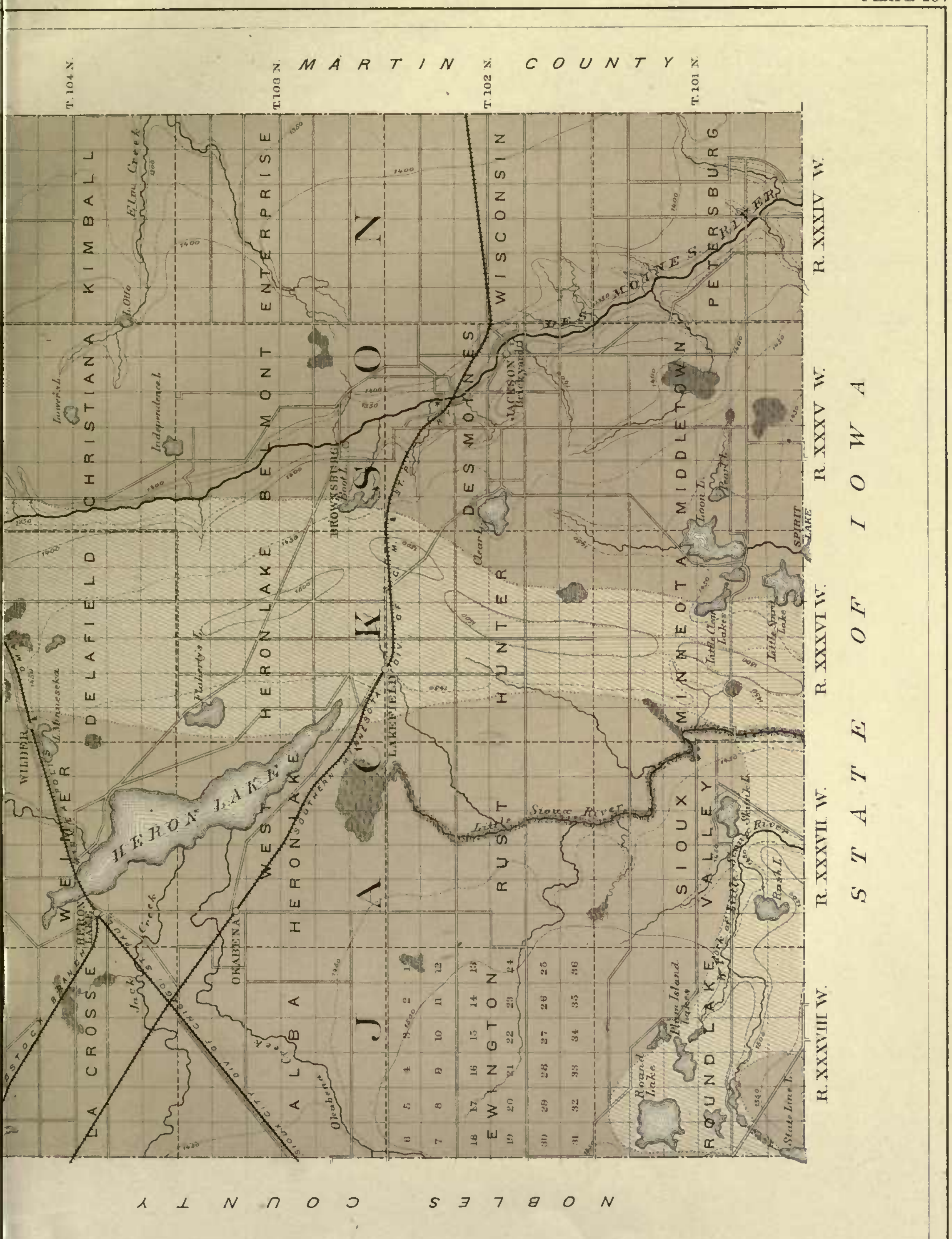
Toward the south and southwest this elevation is for the most part maintained, and even increased, so that the Little Cottonwood river and a fork of the Watonwan river flow northerly across the quartzyte plateau, rising on the drift surfaces further south. It may be presumed that this plateau of quartzyte extends southwestwardly, though covered by drift and by Cretaceous strata, then westwardly and northwestwardly giving the primary basis for the Coteau des Prairies. On this plateau the ice piled its marginal and medial moraines, but in its southern swing passed over it, leaving only a rather uniform layer of till. Quartzyte was struck in the deep well at Heron Lake at 186 feet.

The most of the rest of Cottonwood and Jackson counties consist of smooth or undulating till, though considerably diversified by streams and lakes, which always introduce bluffy shores and more or less timber.

There is, besides, a prominent belt, of roughly morainic contour, which crosses the central part of Jackson county north and south, from three to six miles in width, the most conspicuous portion of this range being the Blue mounds, northwest of Windom, from which the belt runs northwestwardly into Murray county. A spur from this belt extends, probably as a medial moraine, from Windom northwardly about twelve miles. The western portion of these counties rises to over 1,500 feet, the eastern from 1,100 to 1,400 feet.

PLATE 19.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
COTTONWOOD AND JACKSON
COUNTIES.
BY WARREN UPHAM.
Explanation:
Glacial Drift
Till, flat or undulating.
Morainic Till, rolling.
Morainic Till, roughly hilly
Potsdam Quartzyte.
Contour Lines are drawn approximately for each 50 feet above the sea.
REDWOOD COUNTY
BROWN COUNTY
BROWN COUNTY
WATONWAN COUNTY
MURRAY COUNTY
T. 108 N.
T. 107 N.
T. 106 N.
T. 105 N.
COTTONWOOD
ANN
HIGHWATER
GERMANTOWN
WESTBROOK
STORDEN
AMBOY
DELTON
SELMA
ROSE HILL
AMO
DALE
CARSON
MOUNTAIN LAKE
SOUTH BROOK
SPRINGFIELD
GREAT BEND
LAKESIDE
Cottonwood R.
Dry Creek
Dutch Charley's Creek
Highwater Creek
Hurricane L.
Double L.
Watonwan River
N. Branch
North Fork of Watonwan R.
S. Fork of Watonwan R.
Swan L.
Three Lakes
Rat L.
Long L.
Eagle L.
Maiden L.
Bingham L.
MOUNTAIN LAKE
Mountain Lake
BINGHAM LAKE
Clear L.
Cottonwood L.
Glen Lakes
WINDOM
Wolf L.
Summit L.
Fish Lake
The Big Bend
Blue Mounds
Spring Lakes
Twin Lakes
Oaks L.
Talcott L.
Retry L.
DES MOINES RIVER


MARTIN COUNTY
NOBLES COUNTY
STATE OF IOWA
JACKSON
T. 104 N.
T. 103 N.
T. 102 N.
T. 101 N.
R. XXXIV W.
R. XXXV W.
R. XXXVI W.
R. XXXVII W.
R. XXXVIII W.
KIMBALL
ENTERPRISE
WISCONSIN
PETERSBURG
CHRISTIANA
BELMONT
DES MOINES
MIDDLETOWN
DELAFIELD
HERON LAKE
HUNTER
MINNEOTA
WEST HERON LAKE
RUST
SIOUX VALLEY
LA CROSSE
ALBA
EWINGTON
ROUND LAKE
DES MOINES RIVER
HERON LAKE
SPIRIT LAKE
LAKEFIELD
OKABENA
BROWNSBURG
WILDER
Little Sioux River
Round Lake
Loon L.
Little Spirit Lake

There are several old drainage courses in these counties, probably formed in interglacial time, and during the last retreat of the ice-margin. They bear significant relations to the morainic tracts. The Des Moines river once went into Heron lake and thence into the valley of the Little Sioux river and to the Missouri valley. On the retreat of the ice the Des Moines crossed the main morainic belt and entered an ancient valley which was perhaps pre-glacial and turned southeastward in it, forming the "big bend." This pre-glacial valley is excavated, apparently, in some rocky formation, but shows only drift in its bluffs. Below Jackson it is about 100 feet below the brink of the bluffs. Two old water-courses are seen in Germantown, north of the quartzyte plateau, trending southeastward, probably formed during the departure of the last ice-sheet. N. H. W.

PLATES (PAGES) XXI AND XXII.

MURRAY AND NOBLES COUNTIES, 1884. WARREN UPHAM.

These counties afford no rock outcrops. The drift consists almost wholly of unmodified till, and seems to have a great depth. In the till are minor variations to gravel and sand, which afford water in wells. There is also a gravelly plain in Grand Prairie, southwestern part of Nobles county, which was formed by abundant waters flowing from the moraine at the time of the earlier ice-sheet, spreading the coarser materials of the drift over the lower lands. This gravelly deposit, and nearly all the area of these counties, are now covered by a fertile soil. The adjoining areas of till rise from forty to seventy-five feet above this plain.

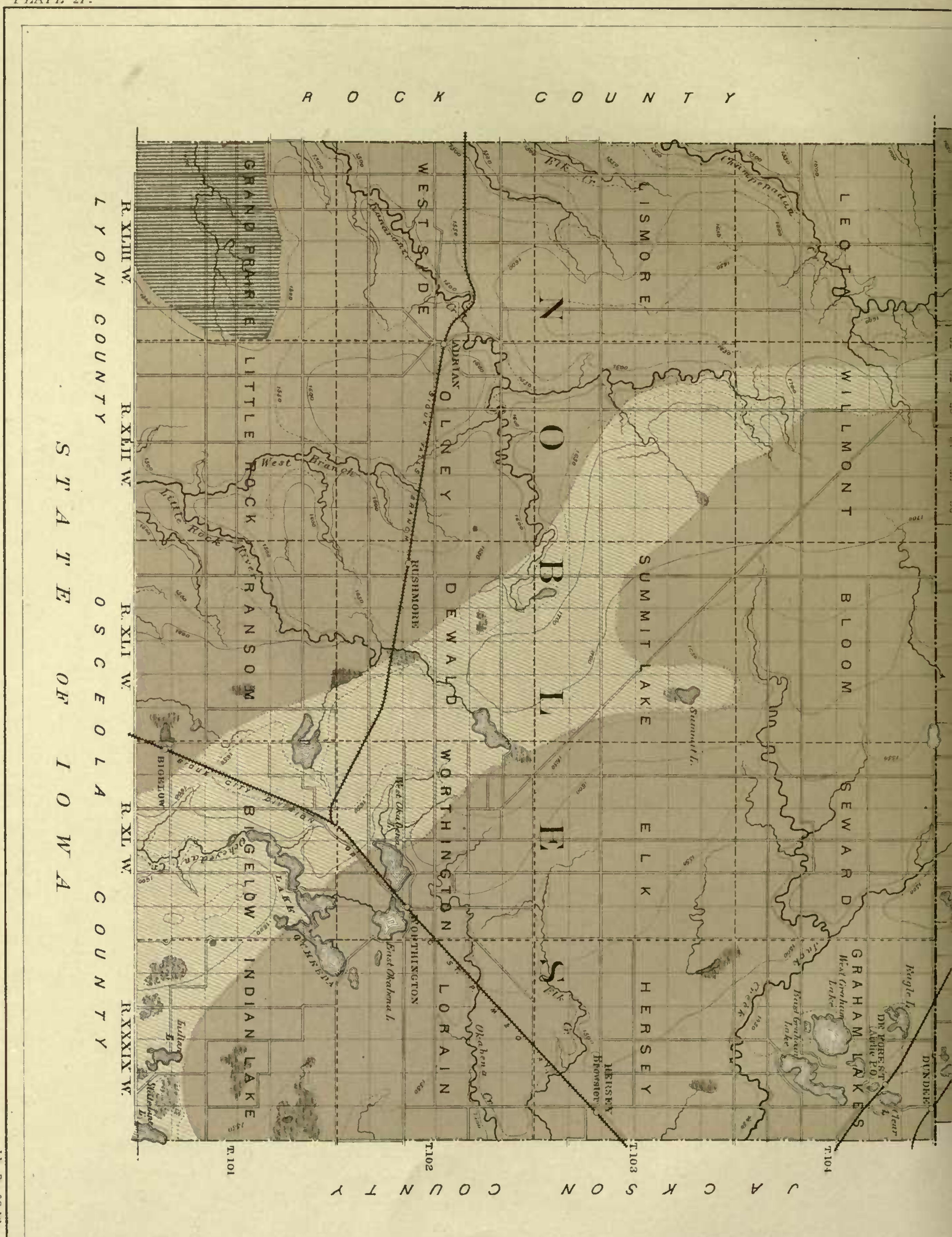
There is more or less gravel to be found also in the hilly morainic belts which cross these counties. These afford reservoirs for springs at lower levels, and serve as sources to the creeks. The Des Moines river rises from such sources in the northwest corner of Murray county.

The western morainic belt, constituting the crest of the principal Coteau des Prairies, rises, in its highest part, in Buffalo ridge, in Murray county, to 1,950 feet above the sea, and it sustains an altitude of 1,800 to 1,900 feet through most of Cameron and Chanarambie townships. Further south, through Nobles county, it has an average maximum altitude of about 1,700 feet. The lowest land in Murray county is in the northeast part of Holly, 1,250 to 1,300 feet above the sea, the extremes in this county being separated, therefore, about 700 feet. The lowest land in Nobles county is at the point where Jack creek crosses its eastern boundary, about 1,420 feet above the sea, and 300 feet below the crests of the morainic belt.

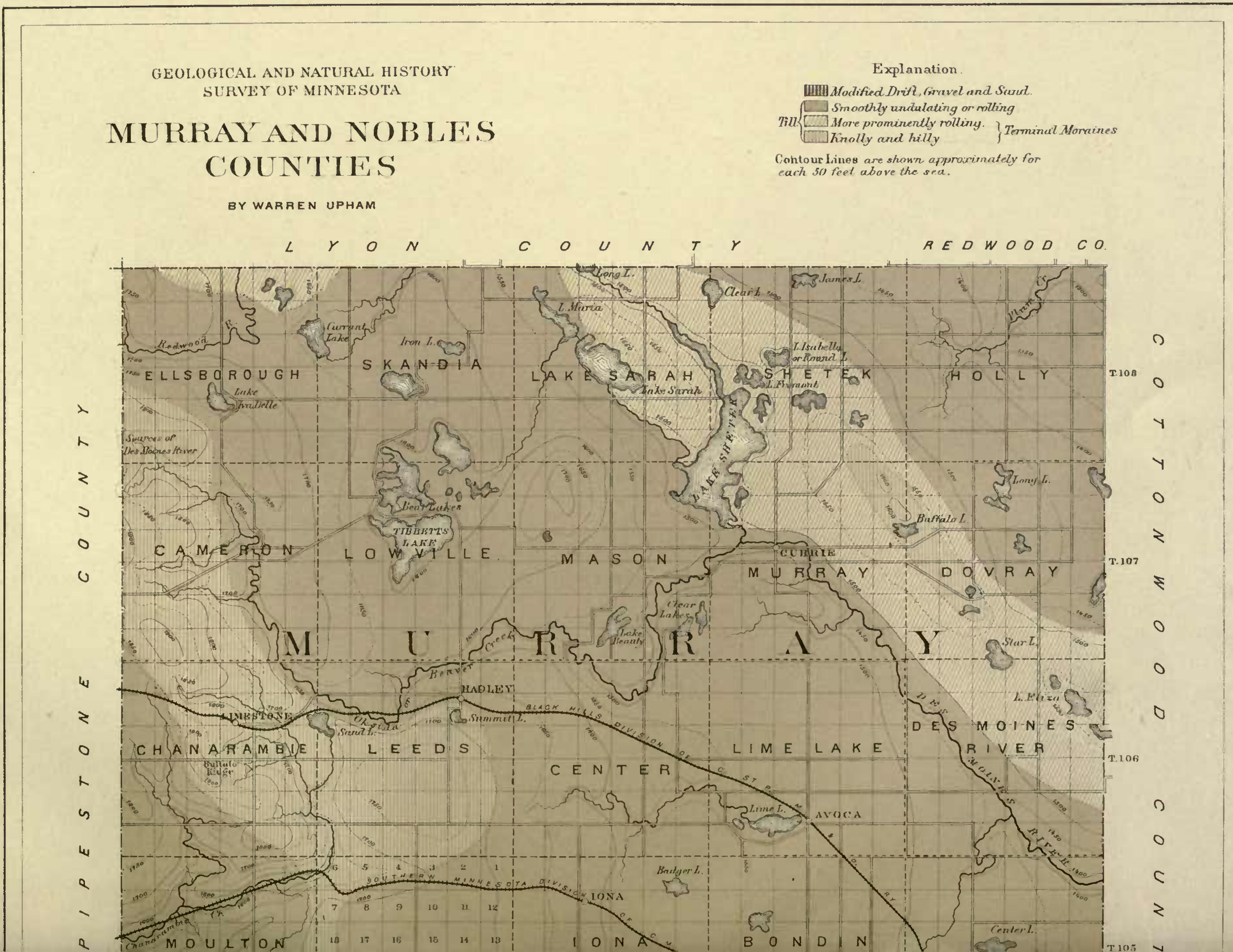
The eroded valleys are from fifty to seventy-five feet deep, and generally a half or three-fourths of a mile wide.

The terminal moraines which cross these counties denote the farthest limit of the ice of the last glacial epoch, there having been a period of rest, and perhaps of readvance, at the place where the eastern, or later, moraine lies. The drift which lies further west and southwest, occupying Nebraska, Kansas and Missouri, was the product of the earlier glacial epoch. It can be inferred that the till to the east of the Coteau des Prairies was of later date than that to the west from the fact that nearly all drainage courses flowing westward take their rise along the eastern margin of the coteau and maintain deep channels through the coteau; while not one that flows eastward rises in the western margin of the coteau. This gave the westward-flowing streams an earlier date than the eastward. The latter could not begin till

PLATE 21.



Julius Bien & Co. lith.


GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
MURRAY AND NOBLES COUNTIES
BY WARREN UPHAM
Explanation.
Modified Drift, Gravel and Sand.
Till
Smoothly undulating or rolling
More prominently rolling.
Knolly and hilly
Terminal Moraines
Contour Lines are shown approximately for each 50 feet above the sea.
LYON COUNTY
REDWOOD CO.
PIPESTONE COUNTY
COTTONWOOD COUNTY
MURRAY
ELLSBOROUGH
SKANDIA
LAKE SARAH
SHETEK
HOLLY
CAMERON
LOWVILLE
MASON
MURRAY
DOVRAY
CHANARAMBIE
LEEDS
CENTER
LIME LAKE
DES MOINES RIVER
MOULTON
IONA
BONDIN
T.108
T.107
T.106
T.105
CURRIE
HADLEY
LIMESTONE
AVOCA
IONA
Lake Shetek
Tibbetts Lake
Bear Lakes
Currant Lake
Iron L.
Lake Isabelle
L. Maria
Long L.
Clear L.
James L.
L. Isabella or Round L.
L. Fremont
Lake Sarah
Long L.
Buffalo L.
Star L.
L. Eliza
Clear Lakes
Lake Beauty
Lime L.
Badger L.
Center L.
Sand L.
Summit L.
Buffalo Ridge
Sources of Des Moines River
Redwood R.
Plum Cr.
Beaver Creek
Chanarambie Cr.
Des Moines River
Black Hills Division of C. St. P. M. & O. Ry.
Southern Minnesota Division of C. M. & St. P. Ry.

after the withdrawal of the ice, which probably buried all the country toward the east and rose several hundred feet above the coteau. While the ice continued, and brought forward its morainic materials, the water that resulted from its dissolution was drained off southwestwardly, and the valleys then formed have subsisted to the present.

N. H. W.

PLATES (PAGES) XXIII AND XXIV.

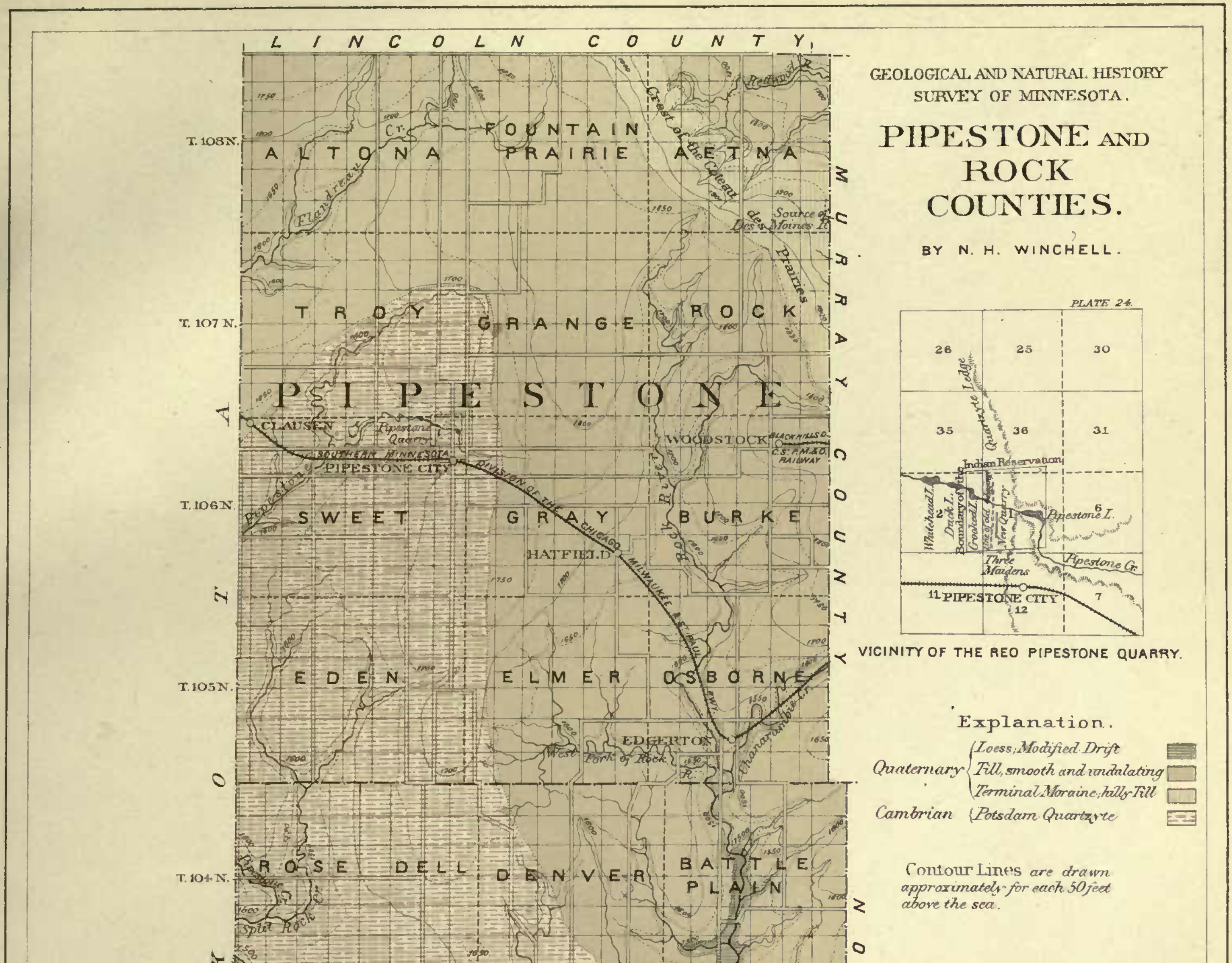
Pipestone and Rock Counties, 1884. N. H. Winchell.

These counties, lying outside of the moraine of the coteau, are still covered with a sheet of till, but this till presents some peculiarities. It has the aspect of greater age, *i. e.*, the boulders are rotted, and many of the pebbles, especially of the limestone, though maintaining their forms in the clay, are largely in the condition of a white residuüm which crumbles easily. The channels cut by the streams are deep, and appear to have been excavated primarily in interglacial or pre-glacial time. In these counties are seen occasional large granite boulders like those which pertain, in counties further east, to the older drift-sheet. Some of these are remarkable for size. The six granite boulders that originally lay on the red quartzyte surface near the pipestone quarry were evidently once united in one mass, being of the same kind of rock, and together they constituted the largest known ice-transported block in Minnesota, making a mass fifty to sixty feet in diameter.

The surface of these counties is generally smooth or gently undulating; but in the northeastern corner of Pipestone county the contour is very rough, being crossed by the crest of the Coteau des Prairies. Here the hills are abrupt, and often very stony, and rise from 100 to 150 feet above the valleys. There are patches of somewhat broken and morainic character further south, as in Spring Water and Elmer, and in Denver, but they cannot be traced to any connection with a morainic origin. They are rather to be attributed to the action of abundant drainage from the ice of the earlier glacial epoch, concentrated locally so as to carry away the finer part of the till, leaving mainly gravel and sand.

There is a modified drift, of a loamy character, covering the southern part of Rock county, in which are found no boulders. This is believed to be a northward extension of the loam of the Missouri valley, and is comparable with that seen in Goodhue county.

The Potsdam quartzyte, which probably underlies all of Pipestone county and the northern half of Rock, affords some small surfaces of bare rock, the principal one being known as "the mound," two or three miles north of Luverne. This rock also contains the layer of hardened red clay known as catlinyte, from which the Indians have long made their peace-pipes. The locality from which it is quarried is near Pipestone city, within a small "Indian reservation." In this catlinyte have been found two fossil species, viz., *Paradoxides barberi* and *Lingula calumet*, indicating



Julius Bien & Co. lith.

the Taconic, or Lower Cambrian age of the quartzyte. (Thirteenth Annual Report, pages 65–72, 1885.) This quarry, and the legends connected with it, play an important part in Longfellow's poem "Hiawatha."

From the summit of the coteau, in northern Pipestone county, 1,900 feet above the sea, to the point of exit of Rock river on the Iowa state line, the descent is about 550 feet. N. H. W.

PLATES (PAGES) XXV AND XXVI.

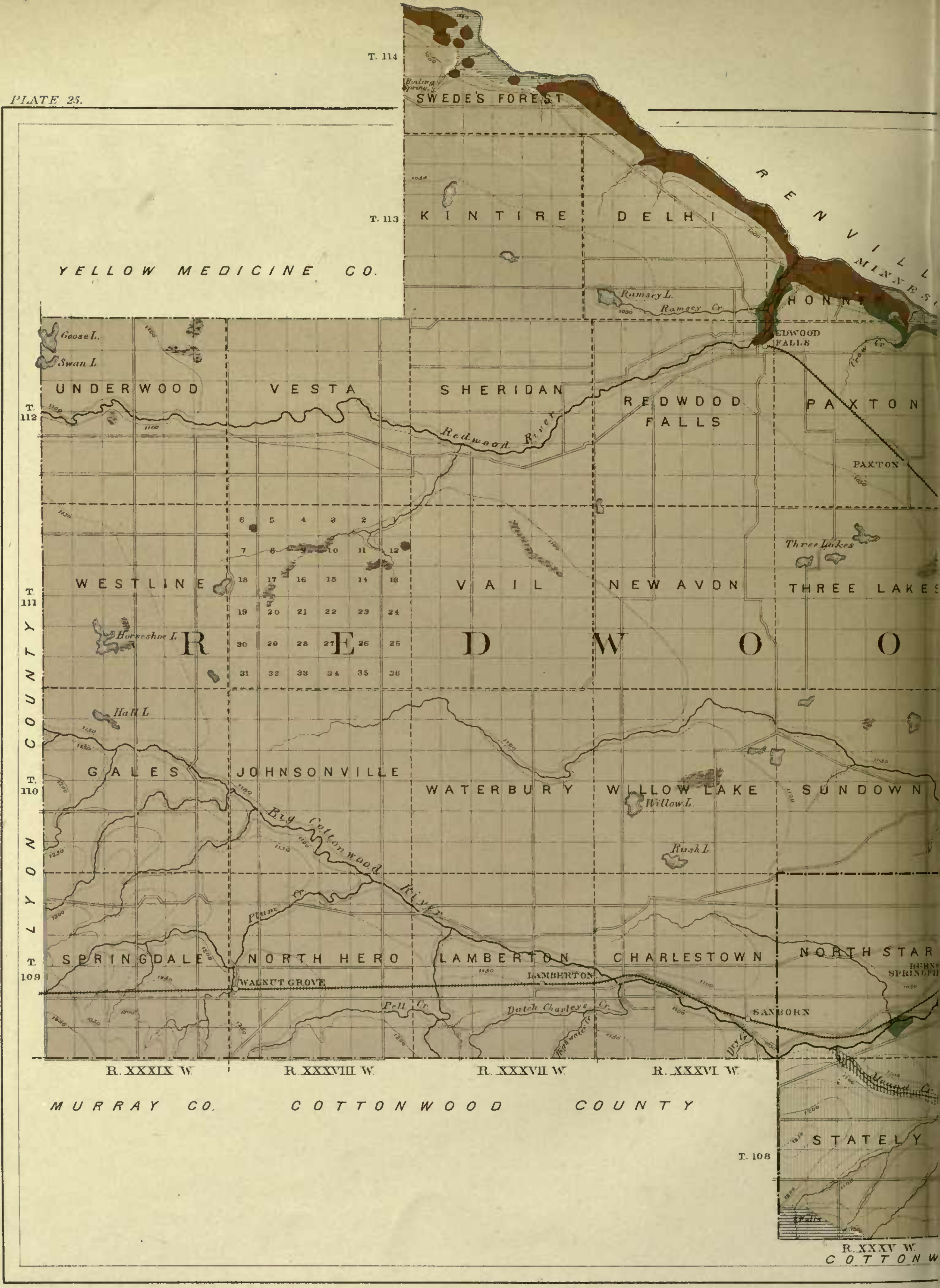
BROWN AND REDWOOD COUNTIES, 1884. WARREN UPHAM.

Along the southern and southwestern limits of these counties the general surface exhibits a noticeable increase of elevation, suggesting that the Potsdam quartzyte, which rises abruptly in northern Cottonwood and northwestern Watonwan counties, strikes continuously toward the west and northwest, giving origin to this increase of hight. This elevation was formerly known as the eastward continuation of the Coteau des Prairies, the crest of which is further west. The streams from this ridge, or plateau, descend to the Cottonwood river, which flows southeastwardly along its base as if it had been determined by a valley formed in glacial time by the barrier of the ice on the northeast. Such stream and valley appears to have united with the Little Cottonwood valley by the gravelly valley occupied by Mound creek in Stately. It probably thence continued through Bashaw and Molligan into Albin, finally being diverted southwardly through the valley of lake Hanska, which appears to lie nearly parallel to the direction of a third moraine which Mr. Upham has indicated in his report on these counties. The water from this drainage probably entered the lake then existing over the region of Blue Earth county and found its outlet into the Des Moines. Through eastern Brown county this glacial drainage course is apparently obscured by till and perhaps by lacustrine deposits.

These counties afford broad expanses of fertile prairie, with only scant timber along the streams or on the borders of the lakes. Although the drift surface appears thus flat, when viewed at large, yet it is found, on closer examination, to possess minor undulations or broad swells varying in extent, hight and direction, generally without any uniform trend, and sometimes oval or nearly round. These give such diversity as to afford local drainage to most of the country, but also cause the occurrence of swamps and lakes. The highest land in Brown county is in sections 31, 32 and 33, Stately, where the hight is 1,200 to 1,250 feet above the sea, and 200 feet above the Cottonwood river in the northern part of Stately, but 100 feet below the top of the plateau a mile further south. The Minnesota river leaves this county at about 778 feet above the sea. In Redwood county the highest land is in the southwest part of Springdale, 1,400 feet above the sea, 300 feet above the Cottonwood ten miles to the north, and 600 feet above the lowest land of this county, at the shore of the Minnesota river at the northeast corner.

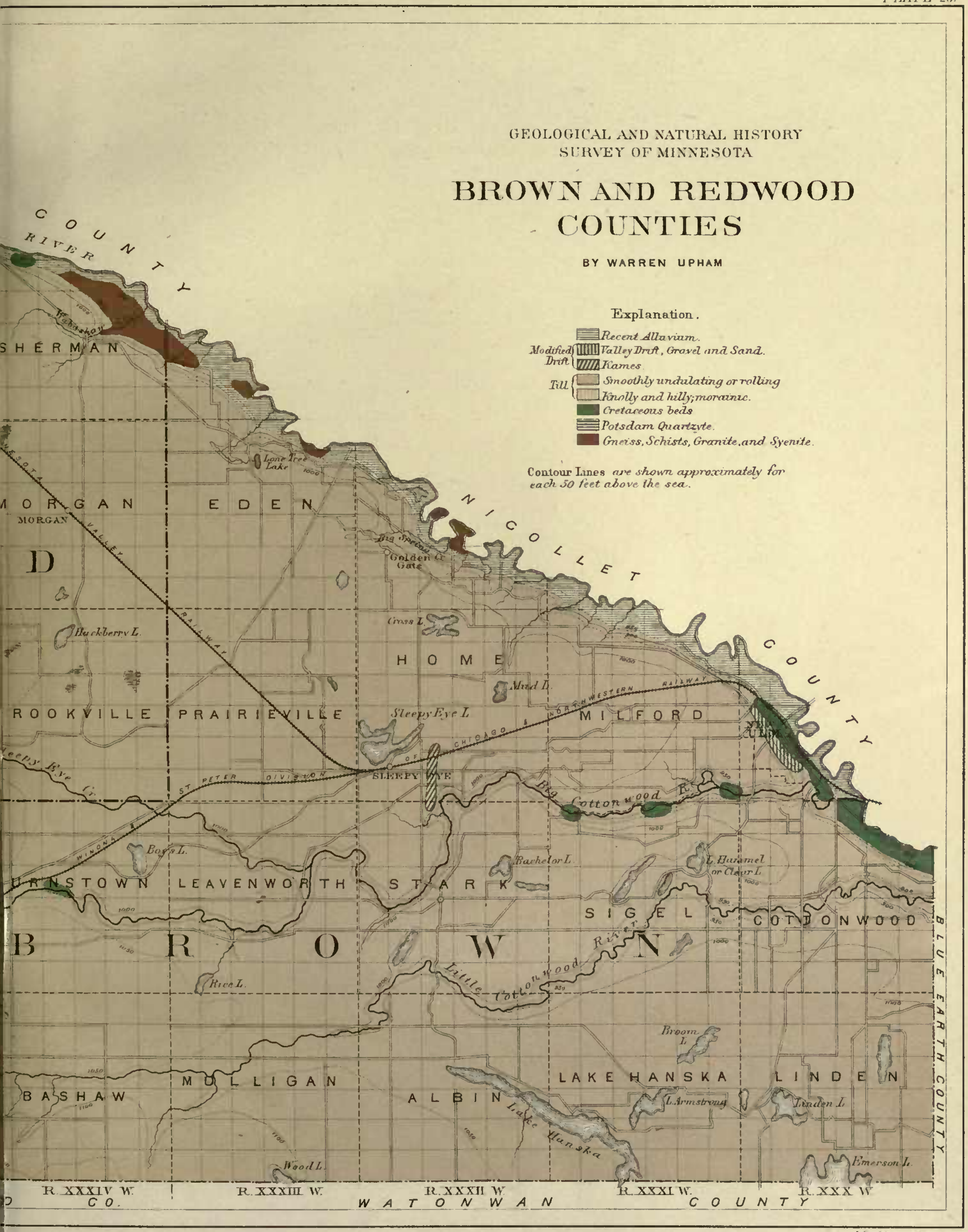
The Archean rocks, with more or less of an overlying of Cretaceous, under the drift, extend under both these counties. The Cretaceous, and especially the drift, serve to conceal the original roughness of the Archean surface, which, however,

PLATE 25.



T. 114
Boiling Spring
SWEDE'S FOREST
T. 113
KINTIRE
DELHI
RENVILLE
MINNESO
HONNE
Ramsey L.
Ramsey Cr.
REDWOOD FALLS
YELLOW MEDICINE CO.
Goose L.
Swan L.
UNDERWOOD
VESTA
SHERIDAN
REDWOOD FALLS
PAXTON
PAXTON
T. 112
Redwood River
Three Lakes
WESTLINE
VAIL
NEW AVON
THREE LAKES
T. 111
Horseshoe L.
R E D W O O
Hall L.
GALES
JOHNSONVILLE
WATERBURY
WILLOW LAKE
SUNDOWN
T. 110
Willow L.
Big Cottonwood River
Rush L.
Plum Cr.
SPRINGDALE
NORTH HERO
LAMBERTON
CHARLESTOWN
NORTH STAR
T. 109
WALNUT GROVE
LAMBERTON
SANBORN
Pell Cr.
Dutch Charleys Cr.
R. XXXIX W.
R. XXXVIII W.
R. XXXVII W.
R. XXXVI W.
LYON COUNTY
MURRAY CO.
COTTONWOOD COUNTY
STATELY
T. 108
R. XXXV W.
COTTONW

PLATE 26.



Julius Bien & Co. lith

presented a substantially base-leveled condition prior to the Cretaceous. The lower portion of the Cretaceous consists, very generally, of kaolin clay which resulted from the decay of the Archean in pre-Cretaceous ages, and which the Cretaceous ocean, in whole or in part, worked over into Cretaceous sediments. This clay, which is sometimes ten to twenty feet thick, is likely to be of value for pottery, but is not at all used at present. The undecayed Archean rocks appear abundantly along the Minnesota valley in the whole extent of Redwood county, and somewhat in Brown county. The Cretaceous is also exposed along the Minnesota at New Ulm, on the Cottonwood, and at Redwood Falls. The Cretaceous contains dicotyledonous leaves, in a sandstone, in the N. E. ¼ sec. 25, North Star, a mile southwest from Springfield station; also near the middle of section 35, Milford, in a similar sandstone exposed in the north bank of the Cottonwood. N. H. W.

PLATES (PAGES) XXVII AND XXVIII.

YELLOW MEDICINE, LYON AND LINCOLN COUNTIES, 1884. WARREN UPHAM.

These counties span the interval between the crest of the Coteau des Prairies and the Minnesota river, from southwest to northeast, and they present the same succession of topographic features as Brown and Redwood counties. A minor portion is drained toward the southwest and south, but the most of the whole area is drained to the Minnesota river. Many streams take their source in the coteau, but these unite at the foot of the plateau, constituting the Cottonwood, the Redwood, the Yellow Medicine and the Lac qui Parle rivers, which thence pursue winding ways across the flat prairies to the Minnesota river. The unanimity with which the small streams unite into these few trunk valleys, a feature which also extends further southeast as well as northwest, indicates not only the wide expanse over which some powerful force operated to control the surface topography and drainage, but points unmistakably to the presence of the glacier as an obstruction to the separate continuance of these small streams. It was while the third terminal (or Antelope) moraine was being accumulated, a few miles northeastward from the foot of the coteau, that these streams were received into a fluctuating lake or broad river-like expanse of water lying approximately between the coteau and the Antelope moraine. On the retirement of the ice from the Antelope moraine this lake was lowered, and the mingled waters found the most accessible courses either northeast directly to the Minnesota, or along the Antelope valley southeastwardly, the Cottonwood river being an illustration of the latter. There are traces of this water not only in the smoothed condition of the surface of the till, but in gravel-strewn, old water courses, the most remarkable of the latter being that which extends through Wergeland and Burton, and into Westerheim. This valley is distinct, twelve miles long, and from a quarter to half a mile in width, lying thirty to forty feet below the flat surface of the till adjoining. It was formed at the time of the existence of the ice-sheet along the region to the northeast, and apparently connected a lake which was on the northern slope, drained subsequently to the Minnesota valley by the Lac qui Parle river, with another which extended southeasterly from Westerheim, and the stream which occupied it must have been a large river. Another channel, which crossed this divide at a later date, is in the town of Omro, and another, similar, in Stony Run. These abandoned channels are comparable to that which exists between Big Stone lake and lake Traverse, the chief difference being that the latter is the ultimate post-glacial residuum of the Minnesota drainage system, and is still active on both sides of the divide.

PLATE 27.

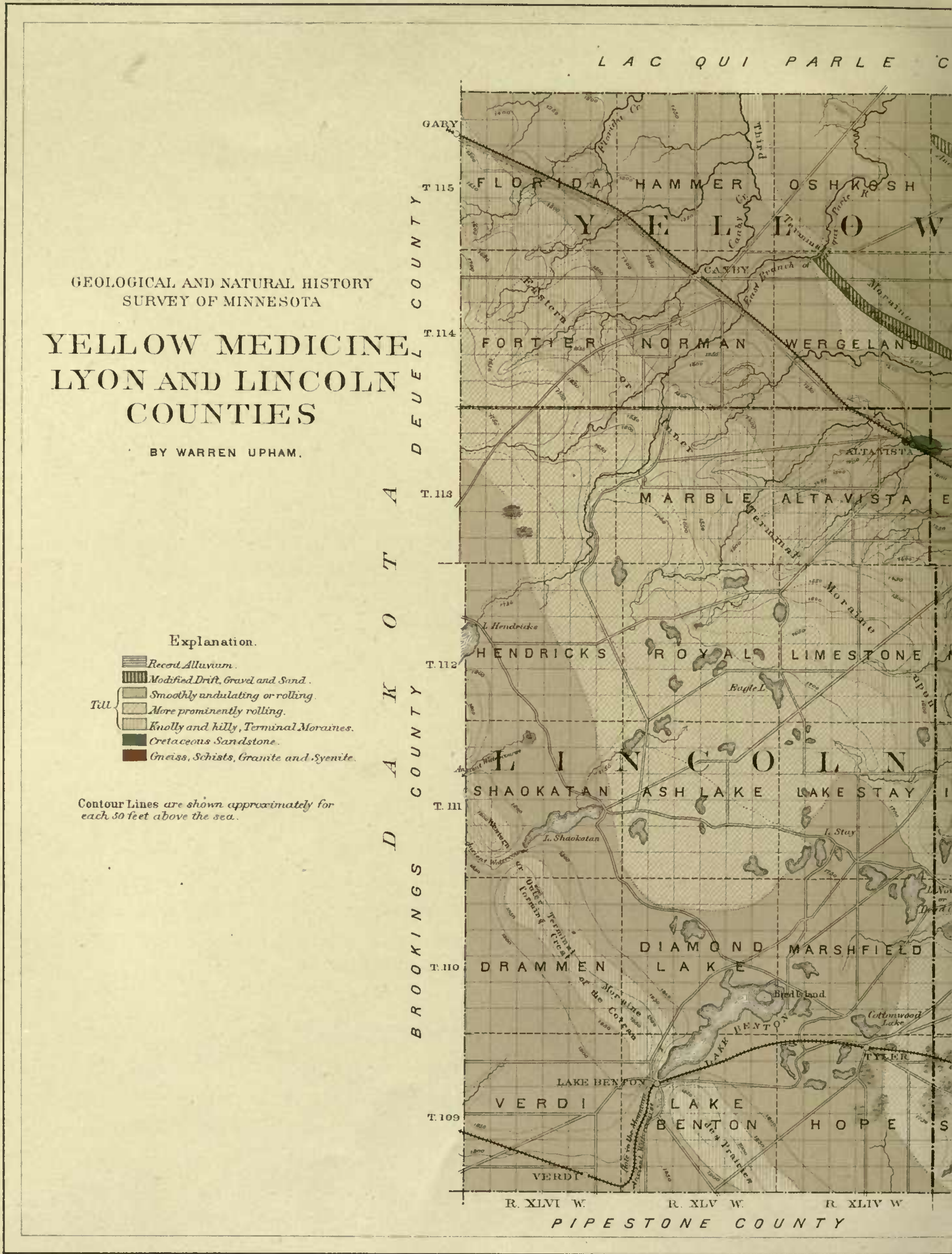

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
YELLOW MEDICINE,
LYON AND LINCOLN
COUNTIES
BY WARREN UPHAM.
Explanation.
Recent Alluvium.
Modified Drift, Gravel and Sand.
Till
Smoothly undulating or rolling.
More prominently rolling.
Knolly and hilly, Terminal Moraines.
Cretaceous Sandstone.
Gneiss, Schists, Granite and Syenite.
Contour Lines are shown approximately for each 50 feet above the sea.
LAC QUI PARLE C
DEUEL COUNTY
DAKOTA
BROOKINGS COUNTY
PIPESTONE COUNTY
GARY
T. 115
T. 114
T. 113
T. 112
T. 111
T. 110
T. 109
FLORIDA
HAMMER
OSHKOSH
YELLOW
CANBY
FORTIER
NORMAN
WERGELAND
ALTA VISTA
MARBLE
HENDRICKS
ROYAL
LIMESTONE
L. Hendricks
Eagle L.
LINCOLN
SHAOKATAN
ASH LAKE
LAKE STAY
L. Shaokatan
L. Stay
DRAMMEN
DIAMOND LAKE
MARSHFIELD
Bird Island
Cottonwood Lake
LAKE BENTON
TYLER
VERDI
HOPE
R. XLVI W.
R. XLV W.
R. XLIV W.

PLATE 28.

Julius Bien & Co. lith

On the coteau are numerous lakes, and there are a few in Lucas, Posen and Echo. The largest is lake Benton, in Lincoln county, lying between the outer and the inner moraines. Most of these counties east of the coteau are monotonously flat, and occasionally swampy, possessing a strong and deep soil. Below the drift are known Cretaceous and Archean rocks. The former holds a little lignite and considerable quantities of kaolin. The latter is exposed chiefly in the valley of the Minnesota, especially at Granite Falls and Minnesota Falls. It rises above the drift in Echo and Posen.

N. H. W.

PLATE XXIX.

BIG STONE AND LAC QUI PARLE COUNTIES, 1884. WARREN UPHAM.

These counties, lying on opposite sides of the Minnesota river, at the western border of the state, were affected differently by the retirement of the ice border across them. They both slope slightly toward the Minnesota river, and as long as that valley was obstructed by the glacier in its slow northward retreat, the drainage water resulting from the ice was embayed, after the ice border left the third or Antelope moraine, in a shallow lake that covered at least the greater part of Lac qui Parle county. By this water not only was the till which was deposited by the glacier smoothed out more evenly, but a distribution of the clayey portions was more or less spread later over the surface of the till proper. This makes this a smooth county with fine soil. On the other hand, while the ice margin was passing still further north and over Big Stone county, the drainage was toward the south, and found easy escape to the Minnesota valley, leaving the till more nearly in the posé given it by the glacier itself. This county, therefore, has more numerous small hills and undulations, frequent lakes and areas of stony surface, while the soil is coarser and occasionally gravelly. They are both essentially and characteristically prairie counties, with very little timber along the bluffs of the streams and lakes.

The glacial water-course seen in Freeland and Garfield is probably of the same date and origin as that noted in Yellow Medicine county, and probably served to connect portions of the glacial lake that lay east from the Antelope moraine. The great river, named river Warren by Mr. Upham, which a little later in glacial time drained lake Agassiz, and which is perpetuated by its diminished descendant, the Minnesota river, presents a similar instance of the practical abandonment of its glacial bed. This abandoned gorge is that which connects Big Stone lake with lake Traverse. The rest of the gorge, excavated by river Warren, is occupied by Big Stone lake and by the Minnesota river below that lake.*

The rocks that underlie these counties belong to the Archean, covered more or less by a nonconformable later coating of Cretaceous. The former are exposed along the Minnesota valley from Ortonville southeastwardly to Marsh lake, and on the shores of Lac qui Parle. The latter is not known in the county, but outcrops in the edge of Dakota, opposite the northwest corner of Big Stone county.

Near Ortonville the granite has been considerably quarried, and furnishes a coarse, even porphyritic, variety with a prevalent light-red color, resembling the so-called Scotch granite. N. H. W.

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*The history of this episode in glacial geology is given by Mr. Upham in Monograph xxv of the *United States Geological Survey*.

Julius Bien & Co. lith.

PLATE XXX.

LE SUEUR COUNTY, 1884. WARREN UPHAM.

This county presents the widest diversity of natural surface dependent on the drift and the forces that produced the drift. A broad morainic tract extends along its eastern border, and also along its southern. The interior of the county, included in the angle between these rough belts, was later largely occupied by a lake caused by the obstruction of the Minnesota valley by the retreating glacier at a point further north. This lake had its latest outlet by way of the valley occupied by lakes Tetonka and Sakata and the Cannon river to the Mississippi, and was another descendant of that which formerly extended over much of Waseca, Blue Earth and Brown counties, having its discharge by way of the Des Moines. Such glacial water, wherever present, leveled the till surface when the till was in the act of deposition by the glacier not only by abstracting the clayey element and spreading it in the depressions further south from the ice border, but by facilitating the even spreading of the till itself. Add to this contrast the phenomena of the valley of the Minnesota river, which are largely dependent on the action of the drift forces, and it becomes apparent that few if any counties of the state offer greater variety of topography or embrace a broader scope of glacial features.

The broad, gravelly terraces, rising 150 feet above the Minnesota river, seen at Kasota, Le Sueur and northeast from Ottawa and elsewhere between Mankato and Fort Snelling, are remnants of a coarse bottom-land of the river, through which the later river has cut its present channel. When this elevated bottom-land was formed the drift was being accumulated, for there is no possible source of the clean, coarse gravel of which these terraces consist, except the till in the act of deposition. The northern portion of the Minnesota valley being ice-bound in the glacier, this bottom-land must have been near the level of outflow of the glacial lake that then covered the region, and hence the drainage was toward the south. The lower terraces which rise about 110 feet above the river, seen at Le Sueur, were formed in a similar way, at a later date, probably at the time the outlet was through the Cannon valley.

This county is within the "big woods," and was originally timbered with a great variety of deciduous trees. The streams furnish some water-power, where flouring and sawmills are in operation. The magnesian limestones at Ottawa and Kasota are quarried for lime and building stone. In the crevices of these rocks at Ottawa are deposits of a kaolinic clay, similar to that seen at and near Mankato, whose origin dates from before the Cretaceous, though probably spread by the Cretaceous ocean. This magnesian limestone is in the Upper Cambrian. That at Clapp's limekiln, near Caroline station, is of the Shakopee, and that at Ottawa and Kasota is of the Lower Magnesian proper.

N. H. W.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

LE SUEUR COUNTY

BY WARREN UPHAM.

Explanation

Quaternary
- *Recent Alluvium.*
- *Modified Drift; valley terraces.*
- *Till, undulating or nearly flat.*
- *Till, rolling, or hilly; Terminal Moraine*

Cambrian
- *Shakopee Limestone*
- *Jordan Sandstone*

Contour Lines *are shown approximately for each 50 ft. above the sea.*

Julius Bien & Co. lith

PLATE XXXI.

RICE COUNTY, 1884. N. H. WINCHELL.

A little more than the western one-third portion of this county has the same morainic characters as the eastern part of Le Sueur county, and was similarly wooded, especially through the western tier of towns. In the northern part of this rolling belt the forest is wanting. It is not altogether certain that this rough surface is due to morainic accumulations alone. It is quite possible that the line of superposition of the Trenton limestone on the St. Peter sandstone was marked, as in Winona and Fillmore counties, by a rock-terrace, and that that terrace was broken and was accompanied by knobs and isolated mounds. The effect of this on the thinner drift sheet is seen in the northeastern part of Rice county. This effect apparently extends across the Cannon valley in Bridgewater and Cannon City townships. It is reasonable to suppose that some part of the rolling surface in Webster, and northward in Scott county, is likewise due to an originally broken rock surface. The same cause operates to increase the roughness of the drift along the Straight river south from Faribault. The southeastern one-fourth of the county is characterized by broad undulating prairies based on the till, and has an older topography than the rest of the county, which is dependent on the later action of the main glacier.

The history of the latest glacier and its drainage in Rice county is very interesting, equalling in that respect the glacial phenomena of Le Sueur county. In the same manner a lake was formed in the Straight valley, which had a discharge to the north branch of the Zumbro river. This is marked by high terrace gravels. When the ice uncovered the Cannon valley the lake of the Minnesota valley was discharged through the Cannon valley, forming a lower series of gravelly flats. Between these two events the Straight river for a time ran over the eastern margin of the ice, forming the remarkable kame which is traceable through portions of Bridgewater and Cannon City townships for a distance of about five and a half miles. The gravel in each instance, whether of the river valleys or of the kame, was derived from the cotemporary drift-laden ice adjacent. The existing terraces are due to the later action of the streams in cutting their present channels into the once continuous gravel plains. Still there is an element of confusion introduced, in any effort to assign the terraces to their cause, by the earlier rock-terraces which have also been covered and obscured by the drift. One is due to the superposition of the Trenton over the St. Peter, and another to the Shakopee over the Richmond sandstone. This pre-glacial topography was not destroyed in Rice county, and probably not entirely in any county. It manifests itself where the drift deposits were laid down thin, as

PLATE 31

Contour Lines are drawn approximately for each 50 feet above the sea.

Julius Bien & Co lith.

along the main valleys and in the counties bordering the driftless area, as described in Houston and Fillmore counties.

Besides the till of the uplands and the gravel of the valleys and plains, there is a pebbly loam or clay which covers much of the eastern half of the county, forming the subsoil and also the basis of the soil. This appears to have been in some way connected with the latest action of the glacial waters, when they were able simply to carry forward but not to wholly assort the finer materials brought forward by the glacier.

The rocks of the county range from the Shakopee, seen from Dundas northward to the county line, to the Trenton, which outcrops at Faribault and along Prairie creek, and underlies the southeastern half of the county. The former is fossiliferous at the limekilns in the Cannon valley, near the north county line, containing Cryptozoon minnesotense and indistinct remains of molluscs. The Trenton also contains the usual varied fossil fauna, embracing cephalopods, brachiopods, gasteropods, bryozoans and occasional crustaceans and corals. The Shakopee is used for quicklime and the Trenton for building stone. In the western part of the county considerable lumber is cut from the native forest, but the fine soil constitutes the chief basis of material prosperity. N. H. W.

PLATE XXXII.

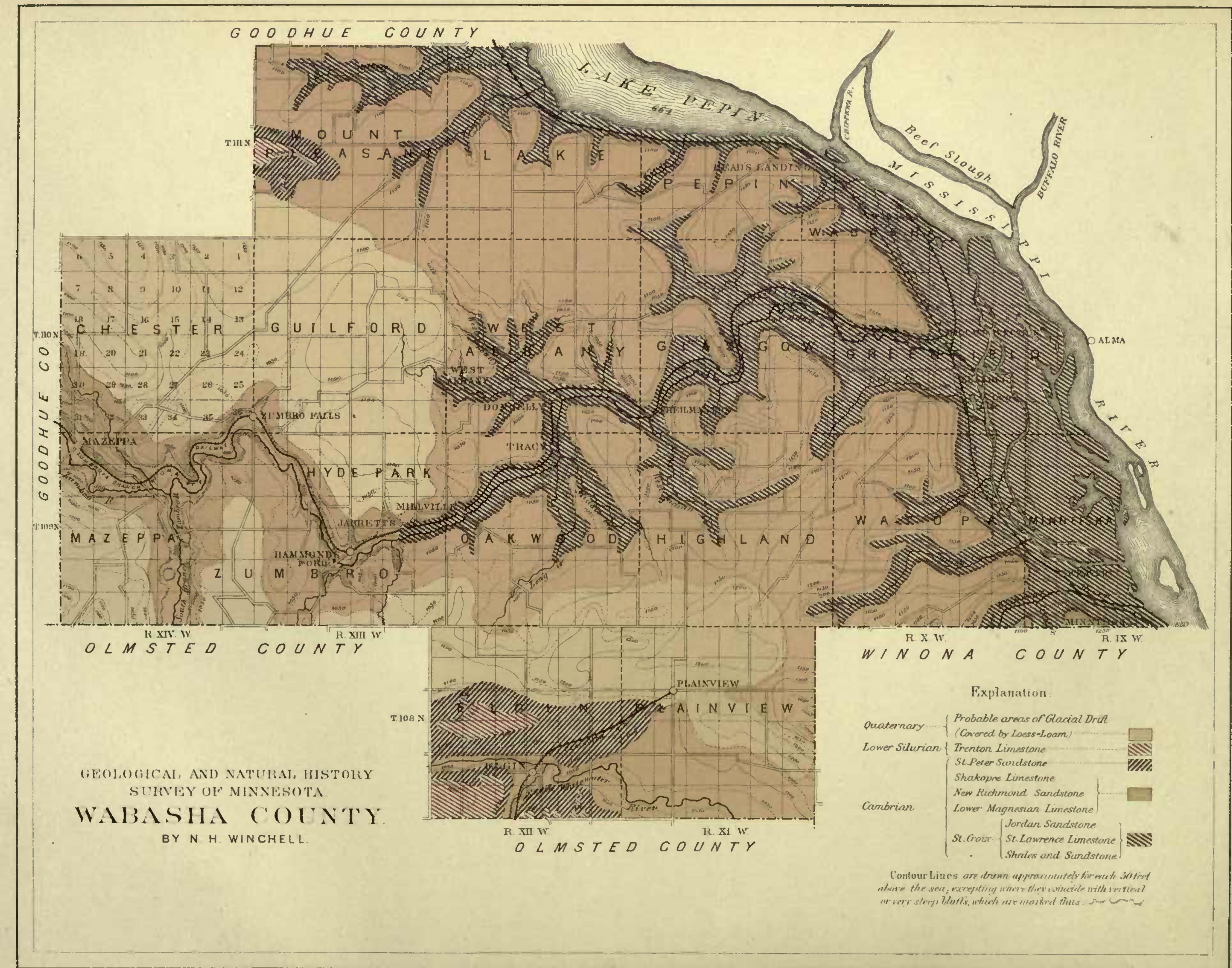
WABASHA COUNTY, 1888. N. H. WINCHELL.

This county is well within the ancient pre-glacial as well as the present valley of the Mississippi. The rock surface was gorged by pre-glacial erosion, and those gorges were not filled by the forces of the glacial epoch, or epochs. The present streams, therefore, flow between rock-walled bluffs from 200 to 400 feet below the general upland. The alluvial bottom lands are broad, usually timbered and fertile, but subject to floods, which are sometimes sudden and devastating. The upland country is undulating, and without lakes. The bluffs of the rock-bound valleys are frequently smoothed down by a great thickness of loam which everywhere covers the county, and in the western part this effect is hightened by a previous overspread of till. The loam and the till together are sometimes nearly a hundred feet thick, but they diminish to nothing along the brow of the bluffs, where their former presence, at least that of the till, is evinced by the existence of a few northern boulders on the lower slopes or at the bottom of the valley.

At a certain stage in the retreat of the ice of the last glacier, as mentioned in connection with plates of Le Sueur and Rice counties (xxx and xxxi), the Zumbro valley was the course of extensive drainage from the Minnesota valley. At that time, while the glacial waters were bearing a gravelly detritus almost directly from the glacier into all the valleys that gave escape for its copious waters, there was apparently a long tongue of ice that projected down the Mississippi valley as in a fiord. This tongue dammed up the tributary streams, causing them to flow at more than 100 feet above their present level, forming the gravel plains from which, at a later epoch, on the entire retreat of the ice, were carved the present high gravel terraces by which the Zumbro and other valleys are diversified. Whether these gravel terraces were formed later or earlier than the loam which widely mantles the general upland, or both, is uncertain, but it is very probable that much of the upland clayey loam antedates the present gravel terraces.

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; the loam, which spreads over the entire county, is uniformly strong and fertile in all the qualities of a good soil. It is often a tenacious clay, practically impervious, but sometimes is covered by sand derived from some outcropping sandstone formation, and again has thin laminæ of fine sand.

The rocks range from the Trenton to the St. Croix formation. The Trenton is found in the tops of the mounds in Mount Pleasant and Elgin townships, and the


GOODHUE COUNTY
LAKE PEPIN
664
MISSISSIPPI RIVER
Beef Slough
CHIPPEWA R.
BUFFALO RIVER
ALMA
MOUNT PLEASANT
LAKE
PEPIN
READ'S LANDING
WABASHA
CHESTER
GUILFORD
WEST ALBANY
GLASGOW
GREENFIELD
MAZEPPA
ZUMBRO FALLS
HYDE PARK
MILLVILLE
JARRETTS
HAMMOND FORD
ZUMBRO
OAKWOOD
HIGHLAND
WATOPA
MINNEISKA
ELGIN
PLAINVIEW
T.111 N.
T.110 N.
T.109 N.
T.108 N.
R. XIV. W.
R. XIII W.
R. X W.
R. IX W.
R. XII W.
R. XI W.
GOODHUE CO
OLMSTED COUNTY
WINONA COUNTY
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
WABASHA COUNTY.
BY N. H. WINCHELL.
Explanation.
Quaternary
Probable areas of Glacial Drift (Covered by Loess-Loam)
Lower Silurian
Trenton Limestone
St. Peter Sandstone
Shakopee Limestone
New Richmond Sandstone
Lower Magnesian Limestone
Cambrian
St. Croix
Jordan Sandstone
St. Lawrence Limestone
Shales and Sandstone
Contour Lines are drawn approximately for each 50 feet above the sea, excepting where they coincide with vertical or very steep bluffs, which are marked thus.
Julius Bien & Co. lith.

St. Croix is in the bottom of the bluffs of the Mississippi and of the Zumbro as far west as Hyde Park. One of the inferior grades of magnesian limestone is quarried at Lake City, at Wabasha and at other places, while in the near vicinity is abundant supply of stone equal to that at Frontenac. N. H. W.

PLATE XXXIII.

GOODHUE COUNTY, 1888. N. H. WINCHELL.

Goodhue county resembles Wabasha in its glacial and pre-glacial history, but it has a more liberal share in the drift materials. There are three main parts of the drift which shade into each other lithologically, but which are rather distinct structurally, viz: the till, the pebbly clay and the clayey loam. Of these the till is the oldest and lies next to the rock. The pebbly clay sometimes appears to be an upward, somewhat modified, condition of the till, as it occasionally carries stones of considerable size, and the clay loam, which constitutes the subsoil on most of the uplands, appears to be composed of a clay like the pebbly clay, but free from pebbles.

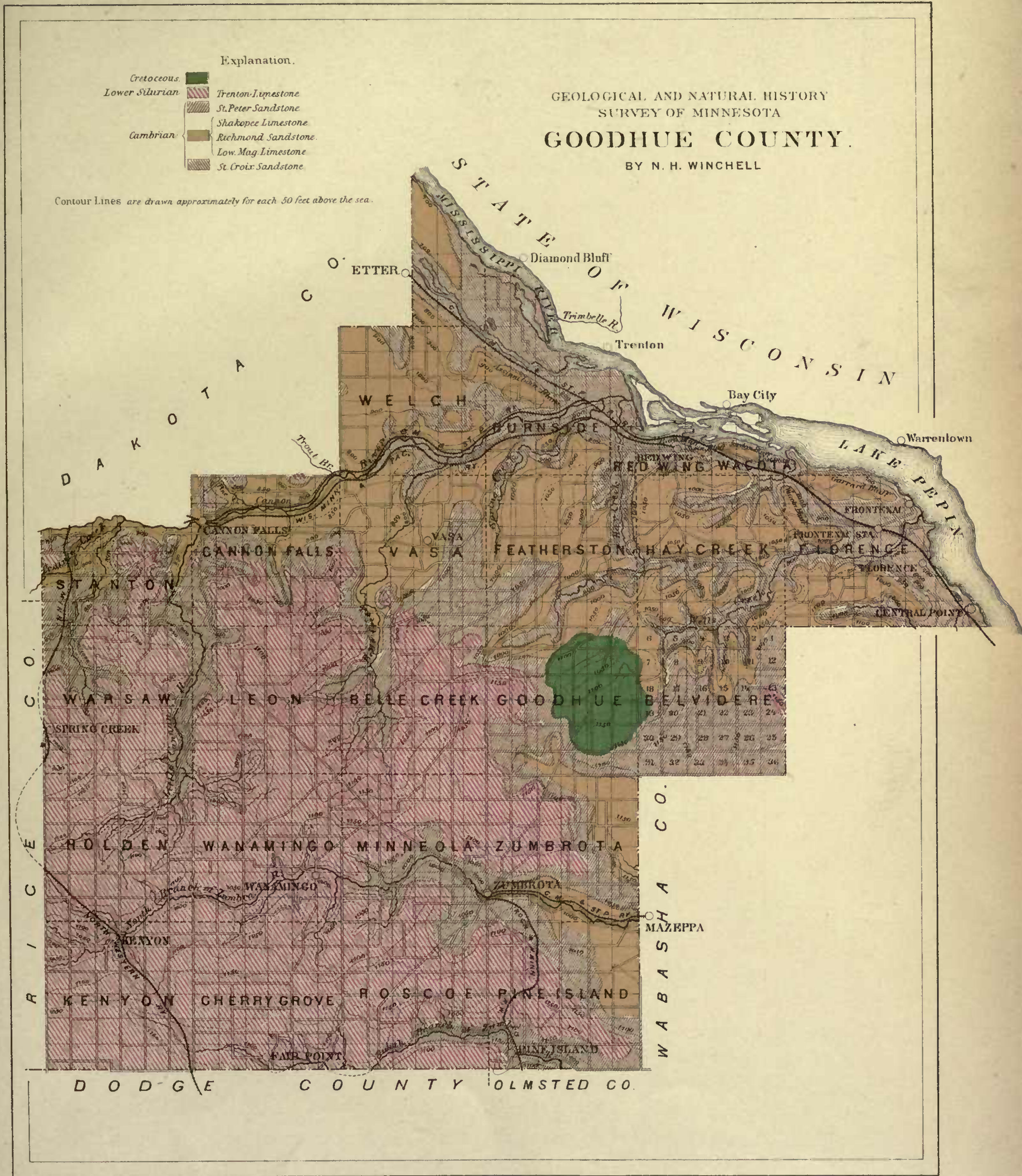
The valleys of the main streams are marked by gravel terraces, as in Wabasha county. These are most developed along the lower reaches of the Cannon, where they probably owe their existence in part to the rapid wash from the nearby glacier of the Mississippi fiord. As in Winona and Wabasha counties there are fragmentary till deposits within the Mississippi bluffs, especially at Florence, beyond the recognized farthest limit of the general ice-sheet, which can be referred to the marginal action of the Mississippi lobe of the main ice-sheet.

While the Cannon valley carried the waters of the Minnesota river (see Rice county), its discharge was not, apparently, directly into the Mississippi river, but in part by way of the Hay Creek valley to Wells creek, reaching the Mississippi at Florence. This continuous valley is terraced with gravel benches, which correspond both in origin and function, to those seen along ancient water-courses in Brown, Yellow Medicine and Lac qui Parle counties. These gravel deposits are the only remains of the effect of the last glacial epoch on the topography of the county. The till and the pebbly clay, as well as much of the loam of the county, are probably due to the earlier ice-sheet.

Besides the rocks of the Upper Cambrian and of the Lower Silurian, this county exhibits some Cretaceous strata. The extensive stoneware works at Red Wing are based on the clays of the Cretaceous from Goodhue township. They are (1888) the largest establishments of the kind in the United States, producing 2,750,000 gallons per year. There are also, at Red Wing, very extensive manufactories of quicklime. The stone taken from the Lower Magnesian limestone at Frontenac is of superior excellence for construction, as evinced by a series of practical tests detailed in volume I of the final report.

Goodhue county is well known for its excellent soil and its great production of wheat, making Red Wing the largest primary wheat market in the United States.

N. H. W.



Julius Bien & Co. lith.

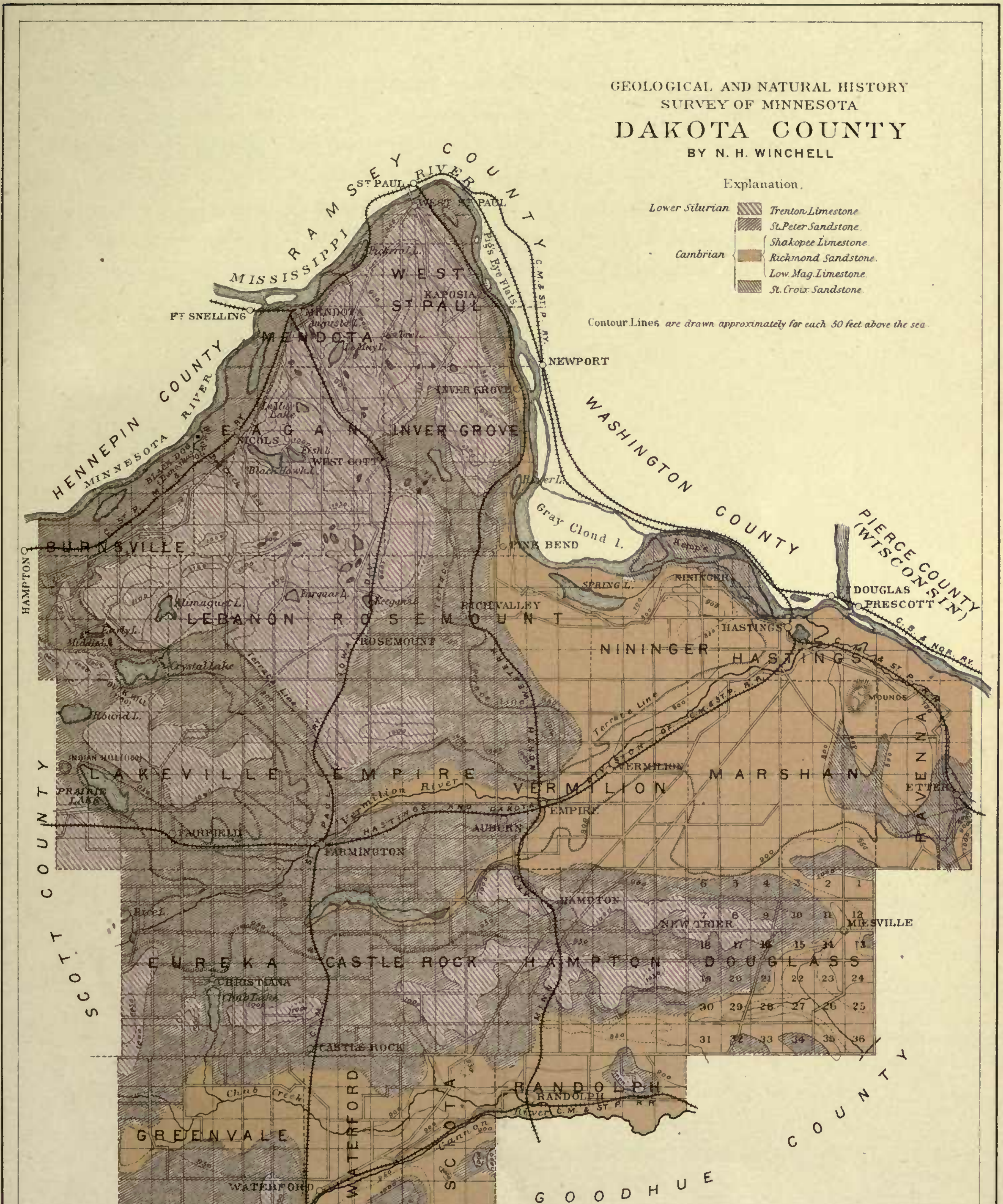
PLATE XXXIV.

DAKOTA COUNTY, 1888. N. H. WINCHELL.

This county embraces great diversity of soil, surface, topography and agricultural adaptability. It lies between the extreme eastern margin of the earlier drift and the morainic deposits of the later, and therefore it was the scene of the tumultuous drainage from the ice-margin of the latter. At the same time, the outrunning strike of the St. Peter sandstone, which always causes a rather sudden change of about 100 feet in the average rock level, is here brought out very remarkably, and coöperated with the later glacial drainage to produce a series of topographic features, the full account of which must be sought in the report on this county in volume II. Again, the great drainage courses of the state, the Minnesota and Mississippi valleys, here unite and form the whole northern boundary. The ancient lakes, formed by the damming of the Minnesota by the later glacier, shrinking in volume and shifting in place from time to time as the ice receded and uncovered lower and lower outlets, the changing glacial drainage courses that cross this county, including five or six long terraced valleys, the gravelly delta plains formed where these debouched into the equally swollen Mississippi, and the final retirement of the ice and the reduction of the streams to their present size—these features, and their connection with the preëxisting gorges of the Minnesota and the Mississippi, conspire to make Dakota county one of surpassing interest to the glacialist. Similarly important glacial features are spread over adjoining parts of Washington, Ramsey and Hennepin counties, next north, and over the counties that adjoin the Minnesota and Cannon valleys toward the south.

The western one-third portion of Dakota county is rough with the hills of the later moraine, this roughness being augmented by the older roughness of the Trenton-St. Peter rock-terrace. Through this rough tract, after the Cannon valley, are found in succession northward the following avenues of glacial drainage: the Chub Creek valley, the Vermilion valley, with its three tributaries (one in northwestern Eureka, the Prairie Lake valley and the Crystal Lake valley), of which the Crystal Lake course is the principal and has a distinct connection with the Minnesota, the Mendota valley passing from near Mendota through section 1, Eagan, to the northwestern part of Rosemount, and its eastern fork, which lies about two miles further east, and lastly the Mississippi valley, from St. Paul southward. These streams had their sources in and on the ice of the later Glacial epoch, or in the glacial lakes of the Minnesota valley, and they eroded and carried away a large part of the earlier drift from the eastern and central portions of the county, burying its remnants more or less completely under the glacial debris of their own turbulent waters.

PLATE 34.



Julius Bien & Co. lith.

The underlying rocks have nearly the same range as those of Goodhue county, probably lacking the Cretaceous, but are less exposed. The Trenton affords interesting fossils at West St. Paul, but throughout the county its limits are indicated more frequently by the shelf-like jog in the topography than by the actual beds in outcrop, since it is much weathered and covered by gravel and loam, or by till.

The northwestern one-fourth part of the county is timbered, and some portions of Douglass and Ravenna, in the southeastern, but the most of the rest of the county is prairie, with scattered groves of oak and poplar. N. H. W.

PLATE XXXV.

CARVER AND SCOTT COUNTIES, 1888. WARREN UPHAM.

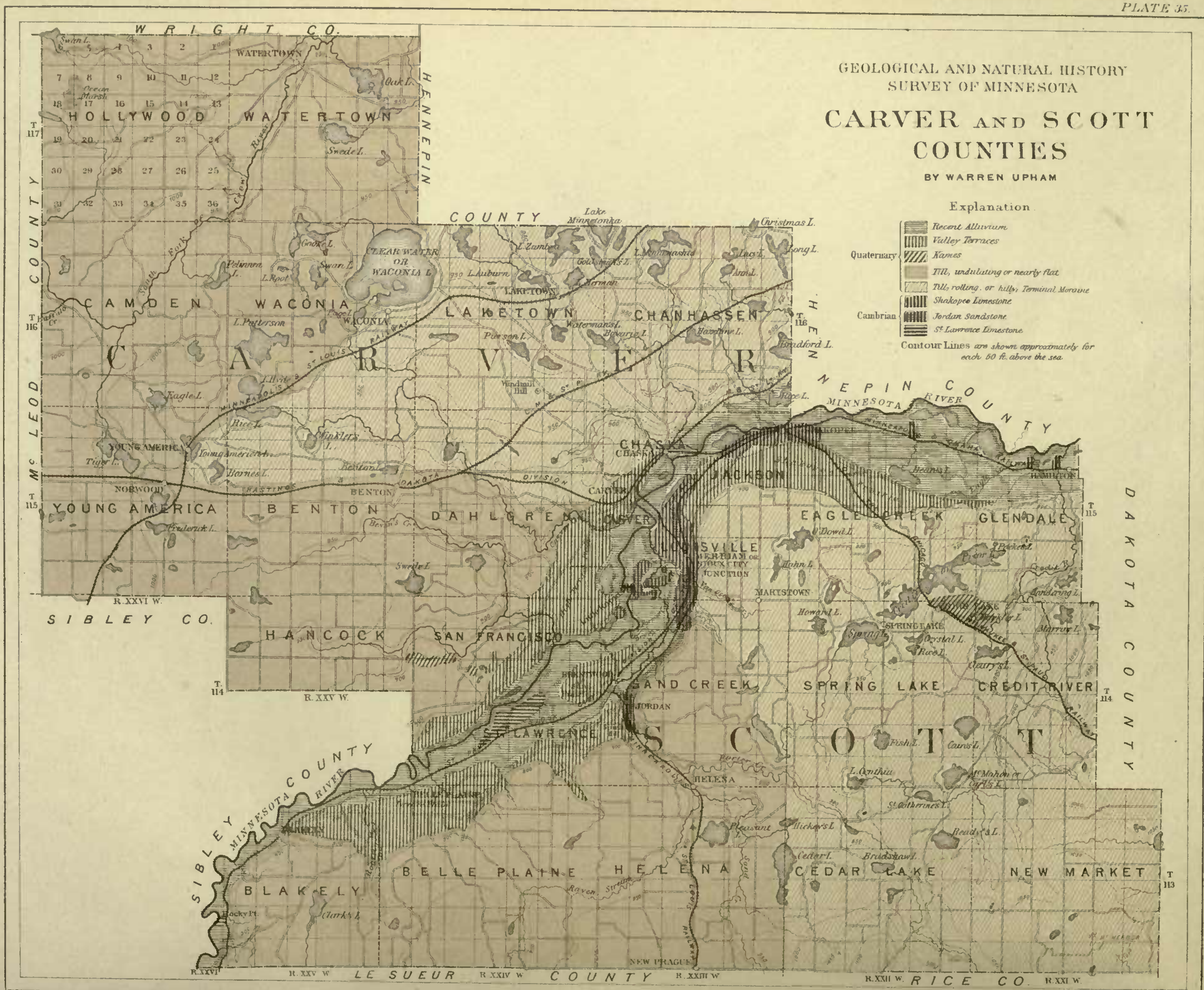
The Minnesota river and its attendant geology compose the chief geological features of these counties. A morainic belt, that of the latest glacier, appears on each side of the river, passing through these counties in an approximate north-south course. It is the same that occupies western Dakota and Rice counties, to the ice of which must be referred the obstruction of the Minnesota river at the date of the existence of the glacial lakes of the Minnesota valley mentioned in connection with Le Sueur and other counties. While the ice margin crossed the Minnesota valley at this place the Minnesota's waters, in whole or in part, reached the Mississippi valley by way of the Cannon or other valleys lying further south. But it is apparent that the water of the valley was so abundant that the drift was subjected to more thorough washing within the valley than elsewhere, this probably being the cause of the extensive gravel and sand terraces that mark the valleys that carried water from the glacier.

Prior to the accumulation of this till and moraine an earlier glacial epoch had deposited an earlier sheet of drift over these counties, and it is certain that similar conditions existed in Carver and Scott counties, at some part of that earlier epoch, as existed at corresponding portions of the later epoch. Hence some of the lower till of the region, and most of the brick clay seen at Carver, Chaska and Jordan, are attributed to that earlier epoch. The later epoch buried the deposits of the earlier under fresh accumulations, but did not materially reduce their bulk by erosion or transportation.

Earlier still, the region had been buried under the Cretaceous ocean. The shale and lignite of the Cretaceous are quite common in the till of these counties, and its kaolinic lower beds went easily into the general drift, augmenting its clayey element.

For a very long period prior to the Cretaceous the region had been dry land. This period extended, as appears from the record of the rocks, from the close of the Trenton in the Lower Silurian, to the Cretaceous submergence. This enormous interval of time, covering Upper Silurian, Devonian, Carboniferous and much of Mesozoic, was sufficient to cause the superficial decay of the old strata that happened to be at the surface in these counties. The region was brought almost to the condition of the base-level of the Archean lying a few miles further north. The kaolinic residuum of the older rocks, whether Archean or Silurian, went into the bottom beds of the Cretaceous, giving the bottom Cretaceous a well-known kaolinic character.

It was during this long exposure that the great gorges in which lie now the Mississippi river and the lower part of the Minnesota, were excavated. In these



Julius Bien & Co. lith.

gorges, in places, are seen the Cretaceous strata, which would not be true if the gorges were excavated since the Cretaceous. These gorges extend below the present river level from 100 to 200 feet. They are thus partly filled with drift, and largely by gravel and sand, as revealed by deep wells at Belle Plaine, Mendota, St. Paul and elsewhere.

These counties are embraced within the wooded tract long known as "big woods," their only prairies being some of the terraces of the Minnesota valley. They are essentially agricultural counties based on the soils of the drift. The roughness of the moraine interferes with farming only in some parts of New Market, Cedar Lake and Credit River in Scott county, although, in general, the morainic belt is much more stony and gravelly than the non-morainic. Large quantities of light-yellow brick are made at Chaska, Carver and Jordan. N. H. W.

PLATE XXXVI.

SIBLEY AND NICOLLET COUNTIES, 1888. WARREN UPHAM.

Excepting the Minnesota valley, and the short valleys of its tributaries, these counties present a nearly flat or gently undulating surface composed of till, whose low divides and swells rise slowly from ten to twenty or rarely thirty feet above the intervening depressions, in which last are frequently marshes or shallow lakes.

Timber covers the northeastern one-third of Sibley county and small scattered tracts about lakes, and along the Minnesota river in Nicollet county; but in general these counties are characterized by prairie.

The Minnesota river lies from 175 to 180 feet below the bluffs at Fort Ridgely; about 200 feet at Mankato; 230 at St. Peter, and 210 to 225 at Henderson and northward.

The soil is fertile and black to the depth of one and one-half to two feet, being about the same in the timbered tracts as in the prairie.

The underlying rocks outcrop only in the lower flats of the Minnesota valley. The Archean is seen in the town of Ridgely, consisting partly of porphyritic granite with abundant coarse, gray crystals of orthoclase and partly of a flesh-colored feldspathic granite not noticeably porphyritic, with patches made up almost entirely of black mica; also a rough-weathering belt of mica schist extends for several rods north and south, dipping toward the west from 40° to 60°.

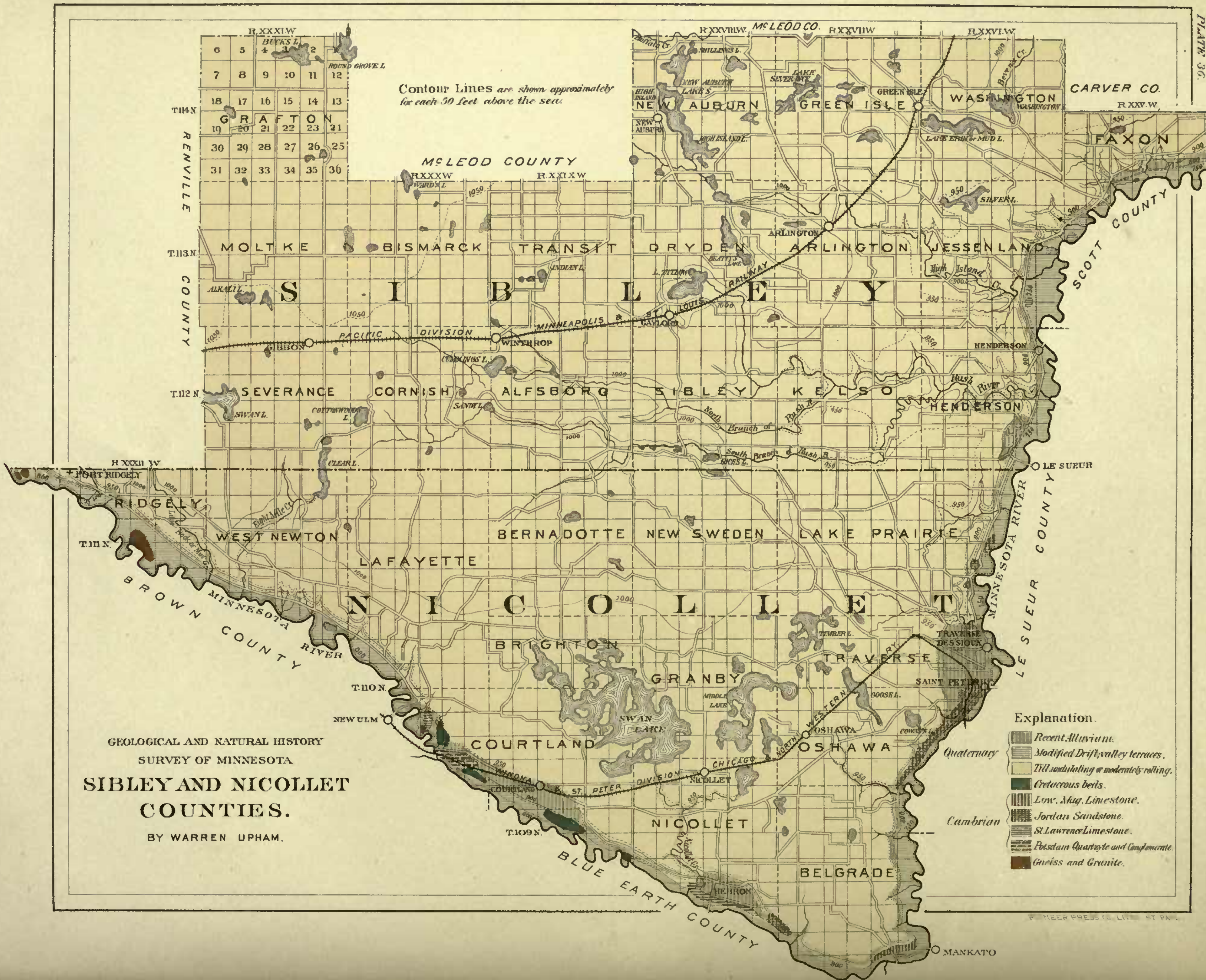
At four miles below Fort Ridgely is the place known to the early voyagers and Indians as Little Rock, consisting of reddish granite and gneiss. This rock is visible about a mile, from northwest to southeast, rising in knobs from forty to sixty feet above the flood plain.

There is also a small knob of red granite in the S. W. ¼ sec. 27, Courtland, opposite New Ulm, which is overlain almost directly by a coarse, reddish conglomerate, the basal beds of the Potsdam.

The age of the Animikie intervened between the granite and the Potsdam, but no trace of its strata are found *in situ* in this part of the state. Its debris, however, has been detected in this conglomerate.* Mingled with abundance of quartz and quartzyte and some of gneiss are many felsyte and taconyte pebbles. This conglomerate is closely followed conformably by the red quartzyte and red shale exposed a little further east, and extending a mile and a half toward the east and southeast, on the north side of the Minnesota river. This quartzyte rises from 100 to 125 feet above the river, with an average dip toward the north-northeast, the whole thick-

American Geologist, vol. xvii, pp. 155-162, September, 1895.

PLATE 36.


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
MOLTKE
BISMARCK
TRANSIT
DRYDEN
ARLINGTON
JESSENLAND
NEW AUBURN
GREEN ISLE
WASHINGTON
FAXON
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
HENDERSON
LE SUEUR
TRAVERSE DES SIOUX
SAINT PETER
NEW ULM
MANKATO
PORT RIDGELY
MINNEAPOLIS & ST. LOUIS RAILWAY
PACIFIC DIVISION
CHICAGO & NORTH WESTERN RY.
WINONA & ST. PETER DIVISION
SWAN LAKE
R.XXXI.W.
R.XXX.W.
R.XXIX.W.
R.XXVIII.W.
R.XXVII.W.
R.XXVI.W.
R.XXV.W.
R.XXXII.W.
T.114 N.
T.113 N.
T.112 N.
T.111 N.
T.110 N.
T.109 N.

ness being perhaps 250 feet. This is the northern arm of the anticline of which the southern arm is seen in the quartzyte ridge of Watonwan and Cottonwood counties, and its age is probably in the Keweenawan (Potsdam) but post-gabbro.

The St. Lawrence limestone appears near the river at Hebron and Judson. It is a rather thin-bedded and argillaceous dolomyte sprinkled with glauconite, and interbedded with glauconitic sandstone. It also appears in Jessenland and in Faxon.

The sandstone seen in Belgrade, Oshawa and at Mankato, underlying a heavy-bedded magnesian limestone, comes next above the St. Lawrence limestone, and is known as the Jordan sandstone. This is rather coarse grained, nearly white, hardly ever fit for construction owing to its friable texture.

But the overlying limestone, quarried at Mankato and St. Peter, as well as at Belgrade and Kasota, is well known for its excellent qualities as a building material. About forty feet of it are exposed in these counties.

The Cretaceous is seen near Fort Ridgely, where it contains lignite, at and near New Ulm, where it affords quicklime (Niobrara), and on section 16, Courtland, where it is a re-cemented quartzyte with fossil wood. N. H. W.

PLATE XXXVII.

McLeod County, 1888. Warren Upham.

The geology of this county is restricted to the glacial deposits, there being no outcrop of the underlying rocks within its limits. It is wholly flat or gently undulating, and these features in the prairie region are continued into the wooded region. About one-half of the county (the northeastern) is thickly wooded with deciduous trees, and in the rest of the county are scattered groves of stunted oaks and of young poplar. The "big woods" run out into the prairie by passing through an increasingly loose fringe of small timber, mostly oak and poplar, which has a width of half a mile, or of two or three miles. It is apparent to the traveler that the width, as well as the density, of this fringe depends on the facility with which it can be attacked by prairie fires moving from the west, and that, in general, the prairies are due to the action of such fires. West of this fringe such groves are confined to the protected eastern sides of lakes, or to the banks of the streams.

Throughout the county the drift consists essentially of till, having a thickness from 100 to 200 feet; but it is divided in some places into at least two parts, which are separated by a stratum containing shells and trees, showing that interglacial epochs occurred, during which animal and vegetable life flourished. This is in accord with the deductions already stated as to the history of the Minnesota valley and as to the interglacial peat deposits of Mower and other counties.

Cotemporary with the accumulation of the gravel terraces of the Minnesota valley, or slightly later, similar gravel deposits were formed by the local washing of the till at other places. Some such are found in the gravel plains and knolls in McLeod county seen in Hutchinson and Helen. They probably exist in many other places not discovered, concealed by the uniform black soil that covers the whole county.

The deep well at Glencoe, sunk in 1896 and 1897, has a depth of 1,640 feet, and supplies abundant good water for the city, but does not overflow. According to drillings and record furnished by Mr. T. M. Paine the well passed through the following formations: Drift, 168 feet; St. Croix, including the St. Lawrence and some red shale, 387 feet; Hinckley sandstone, 381 feet; Fond du Lac sandstone, 157 feet; Potsdam red quartzyte, with beds of red shale (catlinite), 315 feet; red shale and sandstone, 230 feet; bottom of the well at 1,640 feet.

This record is important, as it shows the position of the Potsdam quartzyte (seen at Courtland, in Nicollet county) to be in the midst of a great sandstone formation. The place of the Manitou trap is represented, probably, by the red shale and sandstone that occur above it, and the Cabotian by the great shale and sandstone formation that lies below it. The well did not go deep enough to reach the Animikie.

Julius Bien & Co. lith.

Here are several hundred feet of red shale and fragile red sandstone, showing that it is not necessary to appeal to the region of lake Superior to account for the red element in the till. This red shale and shaly sandstone was also encountered in the deep wells at Belle Plaine, Mankato, Minneapolis, Hastings, and generally in the central part of the state, having a great thickness. It is plainly a part of the conformable strata in the central part of the state lying below the Potsdam quartzyte, and is perhaps the southern fragmental representative of the earlier (Cabotian) eruptives of the Keweenawan. N. H. W.

PLATE XXXVIII.

RENVILLE COUNTY, 1888. WARREN UPHAM.

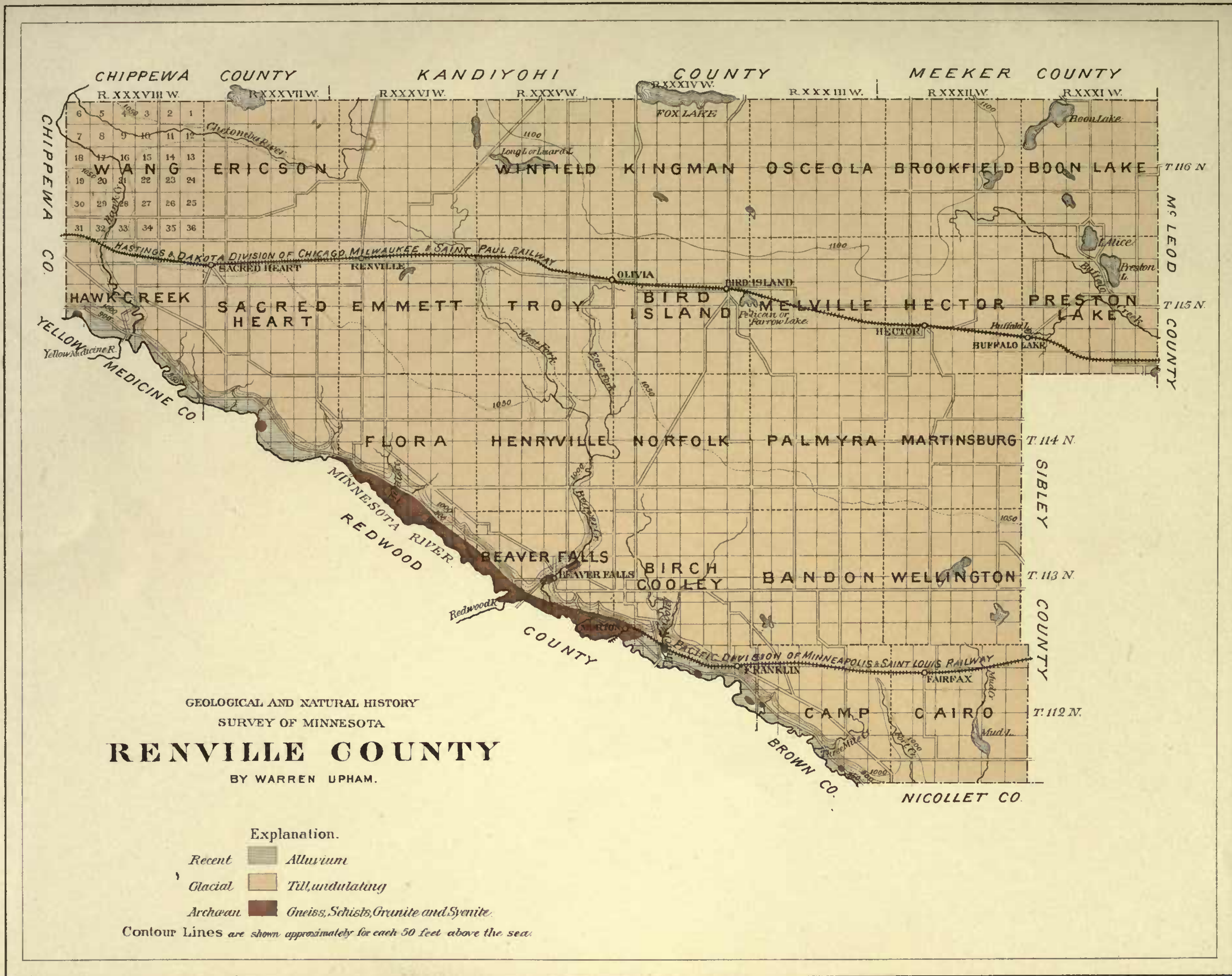
The surface features of western Sibley and McLeod counties are extended westward over this county. There are no rock outcrops except in the valley of the Minnesota river and near the mouths of Beaver and Birch Cooley creeks. The county, therefore, presents a monotonous expanse of prairie, whose undulations are broad and slight. The greatest variety of surface is found in Hector, Melville, Osceola and the west part of Brookfield. In section 5, Hector, are some kame-like hillocks of sand and gravel, which rise about forty feet above the depression along the north side. The bluffs of the Minnesota valley are from 175 to 200 feet high, and the valley is from one to two miles wide. Within it are numerous rough tracts of granitic rock which sometimes rise to 100 or 125 feet above the river itself. These granitic or gneissic outcrops are continuous on the north side of the river for about sixteen miles, viz., from Birch Cooley to the east line of Sacred Heart, and there are isolated granitic areas further northwest as well as southeast. Below Birch Cooley creek similar rocky knobs are abundant on the south side of the river, in the town of Sherman, Redwood county.

The crystalline rocks of this county are very largely composed of granite or massive gneiss, and they are apparently in the southwestward line of strike of similar rocks from Stearns and Morrison counties. At Morton these rocks have been extensively quarried. They afford there a beautifully banded gneiss. It is there cut by large dikes of diabase and it includes isolated masses of dark schist.

The most interesting aspect of the crystalline rocks is seen in the kaolinic product of their decay. This product is sometimes from ten to twenty feet thick. It is abundant at Birch Cooley and in the west part of section 21, Beaver Falls, along the road descending to the Redwood Falls ferry. It has been mentioned in connection with Redwood county. This kaolinic substance extends widely under several counties, and it contributed to the bottom beds of the Cretaceous which, in some cases, have been found to consist of a white, fine kaolin, evidently the result of gentle washing and transportation of the original decayed granite. It is in this assorted and washed condition that this clay is likely to be found of economical value for the making of pottery and china ware.

So far as known the Cretaceous has but a scant representation in Renville county, but it is very probably present under the drift in most of the county, since it exists in Redwood county, next south, and in Stearns county, toward the northeast.

In the drift in the central part of Renville county are found traces of an interglacial soil and forest similar to the phenomena in McLeod county. This vegetable debris lies on quicksand, underneath thirty or forty feet of till. N. H. W.



LITH. PIONEER PRESS CO. ST. PAUL.

PLATE XXXIX.

SWIFT AND CHIPPEWA COUNTIES, 1888. WARREN UPHAM.

These counties are but little more diversified than Renville and McLeod counties. They have the same general prairie surface, based on the uniform till sheet. Still, in the towns of Hegbert, Camp Lake, Kirkhoven, Appleton and New Posen, in Swift county, and in Kragero, Chippewa county, the surface is rolling and morainic. Along the Pomme de Terre river in Shible, Moyer and Appleton is a tract of drift gravel, nearly level, lying fifty feet below the general surface of the drift sheet, and rising from twenty-five to forty feet above the Pomme de Terre. A similar flat gravelly area extends several miles about Benson, lying ten to twenty feet above the Chippewa river. A terrace extends along the northeast side of the Minnesota river from Myers nearly to Montevideo, elevated twenty-five to forty feet above the river. Its greatest width is about half a mile, in section 29, Sparta.

The older till surface is plainly evinced in several places in Swift county, about Appleton, and westward into Big Stone county and southward to Lac qui Parle. It here has the character, not of an ancient soil with vegetation, but of a stony layer from which all soil had been removed prior to the overspreading of the later till. These boulders are closely compacted in till, and they seem not to have been moved, but overridden, by the latest ice-sheet, since they are glaciated in the direction in which the ice-sheet is known to have moved in this part of the state. The interglacial soil must have been removed by water—perhaps by the copious drainage that resulted from the last glacial epoch during the period of its oncoming. As the cold increased, the boulders were held in place by the frozen condition of the earlier till, and were subsequently buried under the later ice and its till sheet.

Very interesting abandoned channels of older drainage occur between the Pomme de Terre and the Chippewa. It appears that the Pomme de Terre and the Minnesota rivers coöperated formerly, when swollen by glacial drainage, in the formation of three islands elongated northwest and southeast, and it is probable that this division of the river was necessitated by the obstruction caused by the great size and abundance of boulders that here accompany the valley, resulting from the disintegration of the stony older till. Such division and expansion of the present rivers, by reason of abundant boulders, is a common feature in the counties further north.

Outcrops of the usual granite and gneiss are frequent along the Minnesota valley, the most important being at Granite Falls and Minnesota Falls. N. H. W.

PIONEER PRESS CO. LITHO. ST PAUL

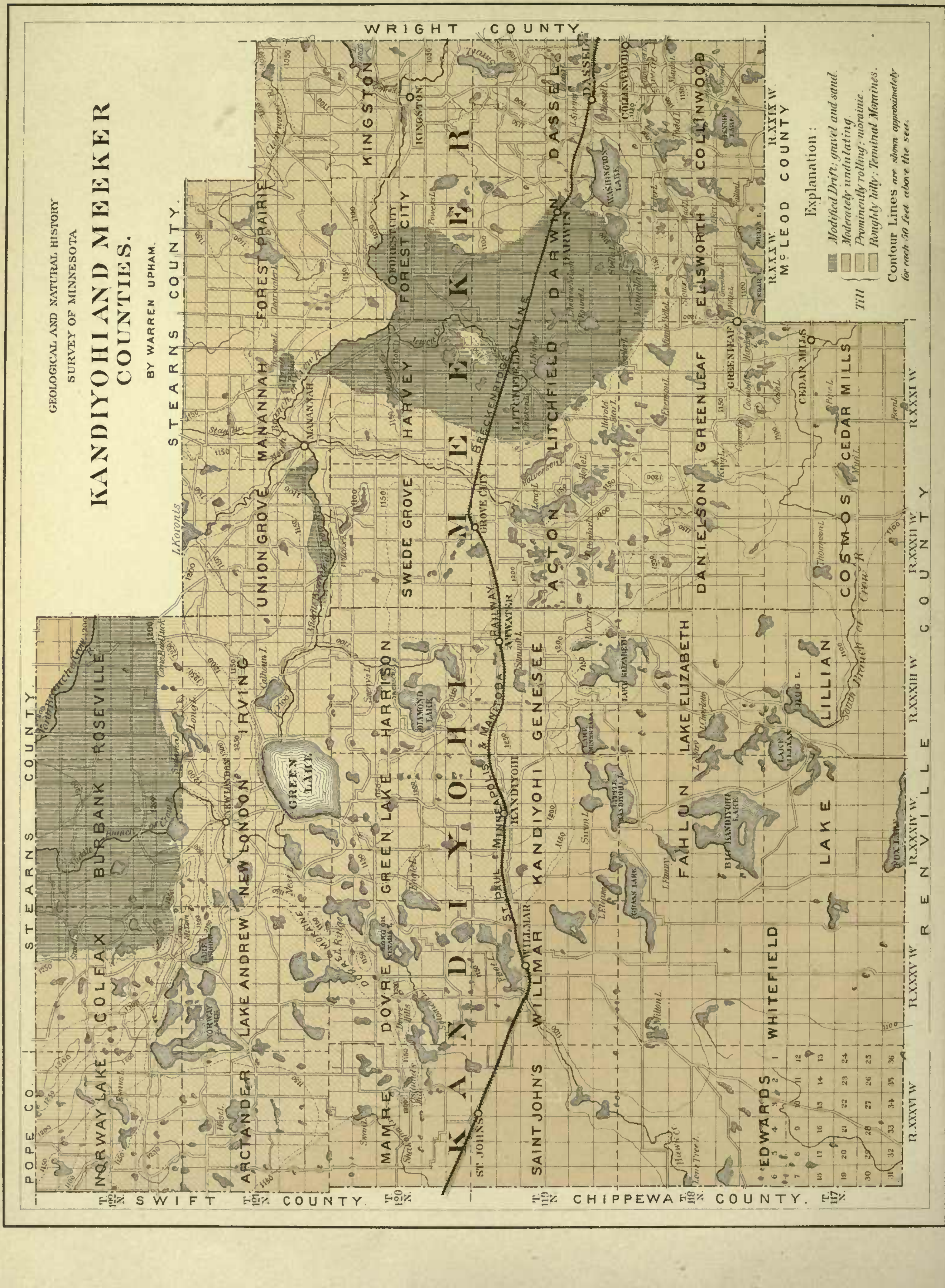
PLATE XL.

Kandiyohi and Meeker Counties, 1888. Warren Upham.

These counties afford no exposures of the underlying rocks, but from the boulders which are abundant in the morainic portions, and from general inference from the known trend of the formations of the state, it is supposed that the underlying rocks are of the Archean. These counties lie between Stearns and Benton counties on the northeast and the abundant Archean outcrops in the Minnesota valley at Redwood Falls and Morton, while the Archean protaxis of the state runs through both these extremes. It is hardly possible, therefore, that the Archean should be wanting under Kandiyohi and Meeker counties. It is possible, however, that isolated patches of the Cretaceous exist in different parts of these counties. Fragments of lignite are sometimes found in the drift, and the soft and yet tenacious nature of some of the till indicates that the Cretaceous element is not wanting in the drift, and this Cretaceous element cannot have been far transported without loss of its distinctive characters. It is likely, therefore, to have had a local origin.

The glacial drift varies, as represented by the plate, from nearly flat to quite rough. The retreat of the glacier margin across these counties was prolonged and tumultuous. It probably involved several stationary epochs, and others of advance and minor retreat prior to the final departure. Its final departure was also not abrupt. During the formation of the moraine, which was due to a long lobe of ice stretching from the northwest from the region of Winnipeg, the surface drainage must have been copious, and its exit was toward the east, reaching the Mississippi river. This was before lake Agassiz began its existence. The extensive gravel deposits which characterize much of the moraine, no less than the condition and forms in which it is now found, attest the thorough washing to which the drift, in some parts of these counties, was subjected. The extensive gravelly plains about Litchfield, and in Burbank and Roseville, and the kames and irregular knolls wherever found are composed of the coarser parts of the drift which were left after this washing. The streams that washed this gravel were the descendants of earlier streams that had washed and distributed other gravel and formed terraces along the Mississippi river. These later streams found their way across Stearns and Wright counties, as evinced by old, terraced watercourses that still exist, which are comparable to those of Dakota county.

One large body of water appears to have left the ice-field in the north part of New London, and to have passed northeastwardly to the Mississippi at St. Cloud. Within the ice-field further west this water was gathered mainly by two branches,



LITH. PIONEER PRESS CO. ST. PAUL.

one coming from the southwest and one from the northwest and uniting in the vicinity of lake Andrew. The location of these streams in Kandiyohi and Pope counties, where they flowed at first on the ice and then in ice-walled valleys, is indicated by the gravelly kames, or long "hogsbacks," which they formed. One extends from Mamre through Dovre and then northward to unite, with more or less confusion in its contour, with the other at the east side of lake Andrew. The other line of long gravel ridges or kames is that which extends northwestward and to the "blue mounds" in Pope county. The latter apparently extends much further, and plainly indicates a long and turbulent river, whose course was frequently disturbed by the shifting of the glacier and by the deposits of drift which it brought forward, but whose course was, in the main, nearly constant along the line of these kames.

This view of these gravel ridges is slightly different from that presented by Mr. Upham in his report on these counties, and on Pope county, who considered them as deposited by ice rather than water. The writer has personally examined only the "blue mounds" in Pope county (Thirteenth Annual Report, page 18), and he found this ridge there composed chiefly of gravel and sand, with boulders. This question should receive further investigation. N. H. W.

PLATE XLI.

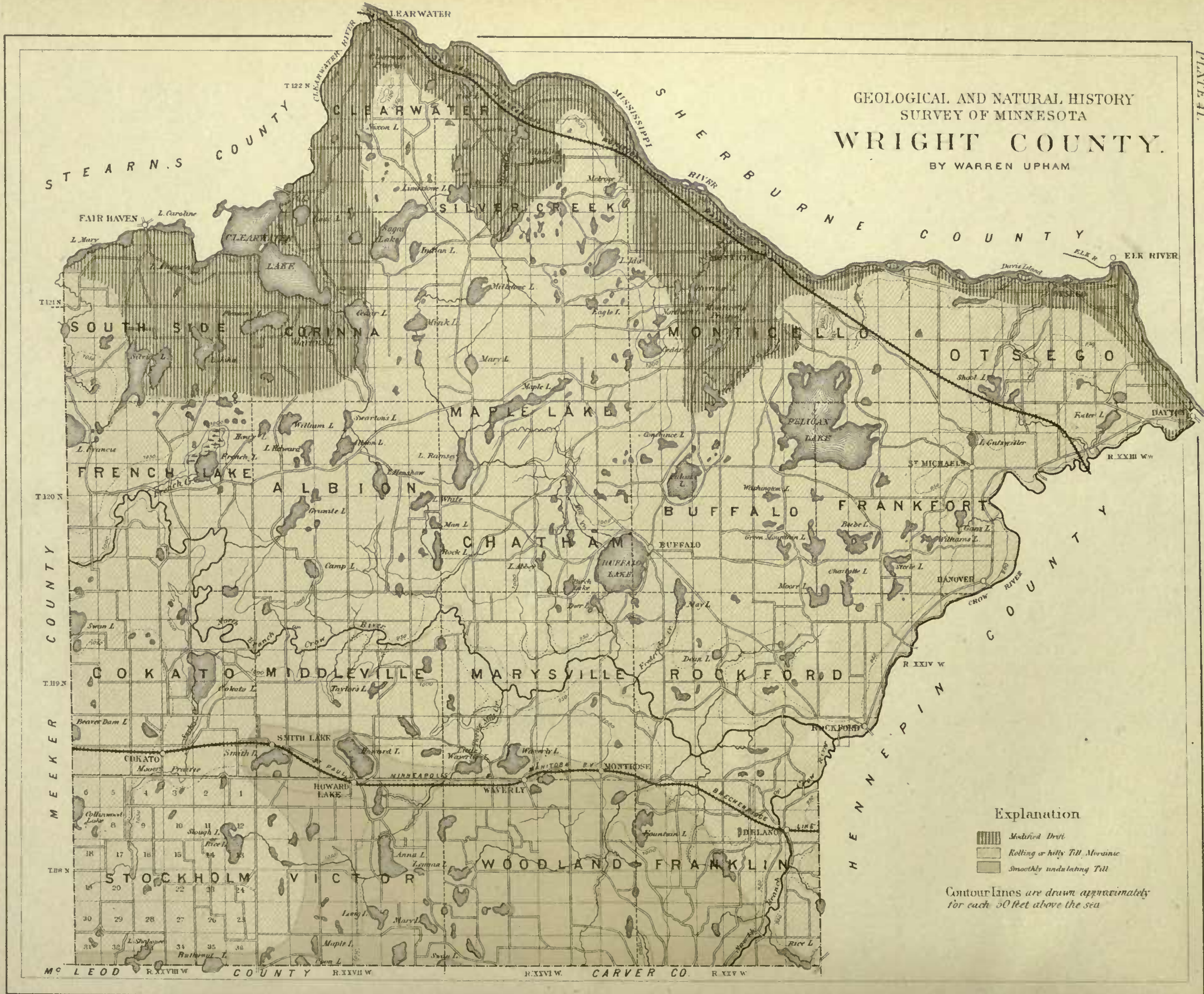
WRIGHT COUNTY, 1888. WARREN UPHAM.

Excepting a few doubtful Cretaceous outcrops, Wright county has no exposures of the underlying rocks. Lignite and Cretaceous shale are frequently found in the drift, and in the gravel along the streams, and it is probable that Cretaceous strata exist undisturbed in much of the county. Of the older rocks it is also probable that on the sinking of deep wells the drill would find some of the Upper Cambrian or the red shales of the Keweenawan, such as met with in the deep wells at Minneapolis, and at Glencoe in McLeod county.

The geological interest of the county, therefore, centers in the drift. It presents no very important features. The county is almost wholly timbered and has a rolling surface, which locally becomes rough, but along the Mississippi and Clearwater valleys are extensive gravel plains and terraces. These terraces are the remnants of a once continuous gravel plain which was formed in the Mississippi valley by the rapid-flowing waters that were discharged from the ice of the glacial epoch, the last sandy and loamy deposits on this plain being formed after the ice was so far withdrawn that gravel could not be transported by the more steady waters. For a long time the Mississippi was swollen by such water and continued to build up these plains. Later, on the shrinkage of the river to its modern dimensions, this gravel plain has been cut into, and in some places largely removed by the river, thus leaving the terraces that accompany it throughout this and other counties. The flat land along the Clearwater river was probably not formed wholly by that stream, but by the Mississippi. Similar flat tracts make inroads on the morainic area, in Silver Lake and in Monticello. Such gravelly plains are found also remote from the river, in other counties, and here, as there, it is probable that the ice of the surrounding upland contributed both the gravel and the water that bore the gravel along, blending with the general flow of the Mississippi only where the waters of the Mississippi extended. In this case there was an extensive bayou, or series of bayous, over which the Mississippi extended in Wright and Stearns counties.

The Crow river in this county, with its tributaries, is practically destitute of such terraces, having a very sinuous course across the morainic deposits. The north branch of the Crow river, however, within the morainic part of Meeker county, is accompanied by an extensive gravel plain at Litchfield. Such catch-basins, filled with water, would prevent the formation of gravel plains along the lower reaches of the valley.

There are two till sheets involved in the drift of the county. The lower one is red, or reddish, and the upper one is gray or bluish gray, but they grade into each



Julius Bien & Co. lith

other. The former underlies the latter and contains debris which came from the northeast, while the latter is abundantly supplied with Cretaceous debris and seems to have come from the northwest. It is not likely that the finer part of either of these tills was far transported, and is reasonably referred to the near vicinity of where it is found. These two tills, in Wright county, may not be the equivalent of the two which in other counties further south are separated by a soil and beds of vegetation, indicating an interglacial epoch, but they may be of nearly cotemporary date, the western ice-lobe having locally encroached on that from the northeast.

N. H. W.

PLATE XLII.

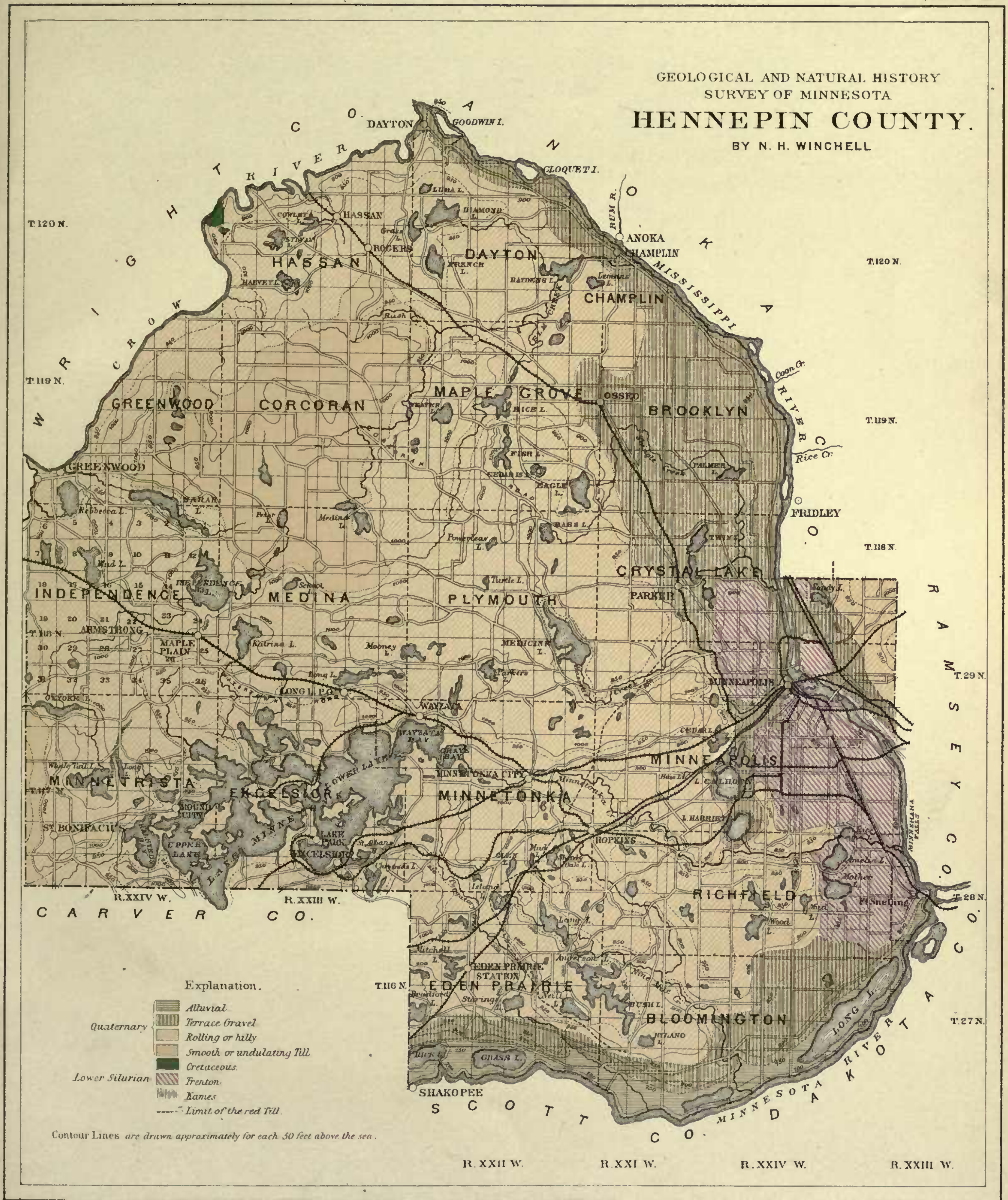
Hennepin County, 1888. N. H. Winchell.

Except small patches of prairie along the terrace flats and the plains that accompany the valleys of the Mississippi and Minnesota, this county was originally timbered, resembling Wright and Carver counties adjoining. There is a large central area, including portions of Corcoran, Medina and Greenwood, which is nearly flat. From this tract the country falls away in a rolling descent in all directions. This more elevated plateau may be underlain by the Trenton limestone, in which case its origin is like numerous buttes that consist primarily of the Trenton and St. Peter sandstone in Goodhue and Dakota counties. Nearly all the rest of the county has a broken surface, excepting only the gravelly plains of the great rivers. Lake Minnetonka and the numerous other lakes that lie to the north and south of it are in the midst of a morainic belt, the depressions of which are sometimes 200 feet below the hills.

The falls of St. Anthony are caused by the passage of the Mississippi across the boundary line of the Trenton limestone and the St. Peter sandstone, the erosible sandstone crumbling away and allowing the limestone to project at the brink of the falls.

The present falls have eroded the gorge from Fort Snelling, but prior to the present gorge another gorge was eroded, which lies through the western part of the city of Minneapolis, running from the mouth of Bassett's creek southwestwardly up that valley to Lake of the Isles, lakes Calhoun and Harriet, and to the Minnesota, probably by the valley of Wood lake in Richfield. The location of this old gorge south of lake Harriet is hypothetical; it may have reached the valley of Nine Mile creek. Still earlier the Mississippi river passed from the mouth of Rice creek, in Anoka county, north of Fridley, directly southeastwardly to St. Paul, entering the present Mississippi at Dayton's bluff. It thus followed the valley of Rice creek to lake Johanna, thence to the depressions occupied now by lakes Josephine and McCarron and thence by the valley that drains southwardly to the Mississippi. This earliest valley is probably that occupied by the Mississippi during that long preglacial time of which we have no history in Minnesota, covering the Upper Silurian, the Devonian and Carboniferous and most of the Mesozoic ages.

The two glacial till sheets found in Dakota, Goodhue and other counties further south, separated by a soil and remains of forests, prove the occurrence of two glacial epochs, or the division of one grand epoch into two sub-epochs. The first one, judging from the nature of the lowest till in Hennepin county, produced a sheet of ice and



Julius Bien & Co. lith.

a layer of till that came from the northeast. It therefore interfered with the course of the Mississippi, compelling it to shift to the west. It remained in its westerly channel sufficiently long to form a gorge from the Minnesota valley to the mouth of Bassett's creek. This, which might be designated an interglacial channel, passes through the western limits of Minneapolis. Then the second (or last) glacial epoch supervened, its forces moving from the west and northwest and depositing the gray till. This filled and totally obstructed the interglacial gorge, driving the river eastward again, when it chose the route which it now holds, and on the retirement of the glacier began the erosion of the gorge now seen extending from Fort Snelling to Minneapolis.

These steps in the history of the Mississippi at Minneapolis have been used to compute the length of time involved, not only in post-glacial geology, but also in interglacial.* The datum for measurement is the ascertained rate of recession of the present falls since their discovery in 1680. This rate is about five and a half feet per year. The time for post-glacial recession would amount to about 8,000 years. That required for interglacial recession about 15,000 years. This result agrees substantially with that derived later from an investigation of the gorge of Niagara, and also with several other methods of computing post-glacial time.

The power generated by St. Anthony falls is from 25,000 to 35,000 horse-power at low water, and it is used to operate the flour mills and other manufacturing industry, as well as to develop electricity which runs the city street cars.

The Trenton limestone and shales in Hennepin county have furnished many fossils, described in volume iii of this report. N. H. W.

*The discussion of the data as to interglacial time will be found in the *American Geologist*, vol. x, pp. 69-81 and 302, 1892, and a discussion of the interglacial climate by Mr. Upham will be found in the same journal, vol. xv, pp. 273-295, 1895.

PLATE XLIII.

RAMSEY COUNTY, 1888. N. H. WINCHELL.

This is the smallest county in the state, containing only 187.15 square miles. Along the bluffs of the Mississippi the Trenton limestone exists, underlain by the St. Peter sandstone, the two together constituting an escarpment which rises about seventy-five feet above the river. These bluffs, however, below the mouth of the Minnesota river, are obscured by the drift of the second glacial epoch and are much smoothed by decay, and this is especially true below St. Paul. Above the mouth of the Minnesota the gorge of the Mississippi is narrow, and has been cut since the last drift was deposited. The highest parts of the Trenton are not seen at the immediate river bluffs, but are so shaly that they have been worn back. They are found in some of the short tributary gorges at St. Paul, at Finn's glen, in Reserve, and were penetrated in the deep well drilled some years ago at the old Reform School, in S. E. ¼ sec. 34, Rose, and showed a total thickness for the Trenton, including the limestone, of 138 feet. The St. Peter sandstone is 150 feet thick and extends below the river level.

This county is mostly covered by a morainic drift deposit, consisting of red till, varying to gravel and sand derived from the red till. There is one important exception to this character of the till, viz., there is a morainic tract in Mound township composed of gray till, analogous both in composition and in geographic place, respecting the red till, to the gray till mounds seen in Marshan in Dakota county. In both cases the surrounding country is covered by modified drift mainly of gravel and sand, and the gray till mounds rise boldly and very conspicuously out of this flat modified drift plain. The age of this gray till may not be the same as that which is spread widely over the state west from Ramsey county, but it may date from the earlier glacial epoch.

The northern one-third part of the county is rather flat, and in the northeastern it is plain that the ancestral lake from which White Bear, Bald Eagle and other lakes are the derivatives, spread over much more territory, having deposited a fine, laminated, gray clay which extends into Anoka and Washington counties, constituting the subsoil over a wide tract, including Forest Lake and Centerville. This glacial lake might be called lake Mahtomedi. A similar lake, which had a short duration in Rose, has been named lake Hamline by Mr. Upham.

Along the Mississippi river is a distinctly terraced contour. Besides the terrace flat formed by the Trenton limestone, there is a gravelly terrace, most marked in West St. Paul and extending into Dakota county, rising about fifty feet above the river.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
RAMSEY COUNTY
BY N. H. WINCHELL
Explanation.
Rolling or hilly Till
Flat or underlating 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.
ANOKA COUNTY
HENNEPIN COUNTY
WASHINGTON COUNTY
R.23
R.22
T.30
T.29
T.28
MOUND VIEW
WHITE BEAR
NEW CANADA
ROSE
ST PAUL
RESERVE
McLEAN
MISSISSIPPI RIVER
Minnehaha Falls
Fort Snelling
Pikes Island
MENDOTA
HAMLINE
MACALESTER
UNION DEPOT
COMO PARK
STATE FAIR GROUNDS
EXPER. FARM
Fountain Cave
PIG'S EYE
Grand Marais
Pleasant L.
Turtle L.
Bald Eagle L.
White Bear L.
Birch L.
Goose L.
Lamberts L.
Vadnais L.
Big Bass L.
L. Johanna
L. Josephine
St Paul Park
Bennett L.
Robinson L.
Savage L.
Gervais L.
Fitzhugh L.
McCarron L.
Phalens L.
L. Como
Beaver L.
Silver L.
Tanners L.
Snail L.
Island L.
Grass L.
Round L.
Long L.
Wild Rice L.
Rice Creek
Otter L.
Rice L.
Duck L.
Sandy L.
Mud L.
Mud Hole L.
Marstons L.
Kettle River Road
MINNEAPOLIS SAULT ST. MARIE & ATLANTIC R.R.
ST. PAUL & DULUTH R.R.
WIS. CENT.
CHI. ST. P. MINN. & O. R.R.
ST. PAUL & N. PAC. R.R.
ST. PAUL MINN. & MANITOBA R.R.
CHIC. MIL. & ST. PAUL R.R.
COMO AVE.
UNIVERSITY AVENUE
CASTLE
WHITE BEAR

There are several artesian wells at West St. Paul which supply a pure water, nearly soft, useful for all domestic purposes. It rises above the natural surface fifteen to thirty feet. They are located on the alluvial flat, but they derive their water from the St. Croix sandstone at a depth of about 300 feet. The borings for these wells prove the great depth of the gorge of the Mississippi at St. Paul. They pass through about 100 feet of fine gray clay, suitable for brick, which lies on the St. Croix sand rock. Water rises immediately on striking this sand rock and increases with the depth of the drill. N. H. W.

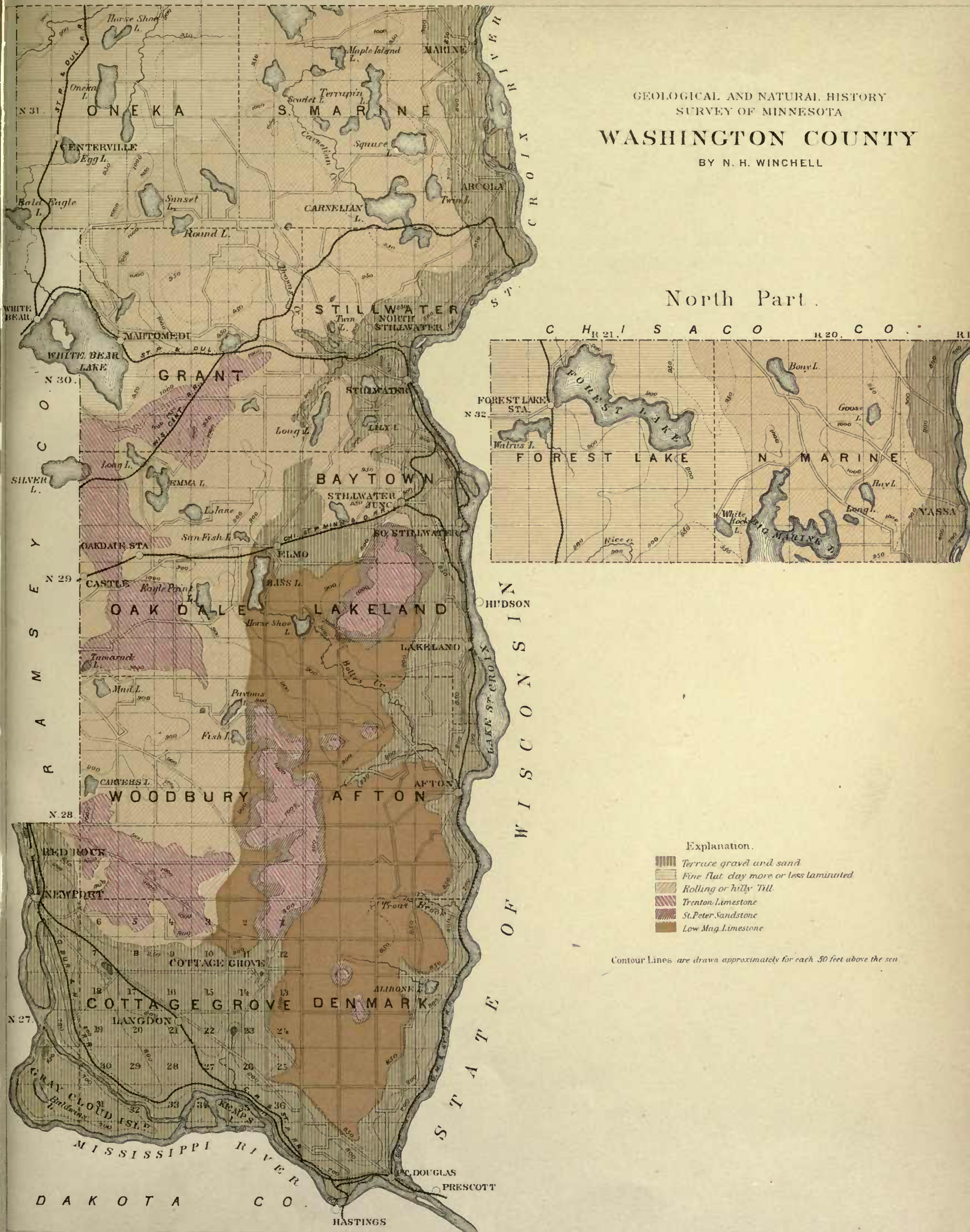
PLATE XLIV.

WASHINGTON COUNTY, 1888. N. H. WINCHELL.

On the eastern and southern boundary this county is surrounded by deeply excavated gorges, occupied by the St. Croix and the Mississippi rivers. The water surface in these gorges is from 250 to 300 feet below the adjoining uplands. The rocks cut by these excavations are, near the brink, limestones and sandstones of the Upper Cambrian, but at a mile or two back from the brink the St. Peter sandstone and the Trenton limestone give a further elevation, which, at Lakeland, carries the surface to 383 feet above the St. Croix.

The immediate bluffs of these valleys are frequently composed of gravel and sand, which forms terraces bordering both valleys, rising, at Lakeland, to the maximum hight of 233 feet above low-water level of the St. Croix. The gravel strewn at this altitude is comparable with the gravel forming elevated plains in Dakota county, such as those of Rosemount, Nininger and Marshan. Extensive elevated gravel plains of this kind characterize the southeastern part of Washington county. They were formed probably when the ice of the last glacial epoch was still present in the morainic tract further north and west, and supplied the till from which the rapid drainage washed out the gravel, carrying the clayey ingredient to more southern latitude. These higher plains can hardly be attributed to the action of the river proper, but to that earlier stage of glacier drainage when the rivers had not yet taken form, but when the waters spread widely everywhere at all levels, springing directly from the dissolving glacier. At lower levels are more constant and distinctly fluviatile terraces. One is about 130 to 150 feet above lake St. Croix and another about seventy-five feet above the same.

These plains are separated from the northwestern part of the county by a rolling belt of moraine of red till which is the northern extension of that of Dakota county. It runs to the vicinity of Taylor's Falls, in Chisago county, and leaves the state. This rolling belt of red till drained southwardly in the southern part of Ramsey county, but on the north side of the Ramsey county divide, owing to the natural slope being northward, and the damming up of the northward outlet by the continuance of the glacier further north, a small glacial lake was formed over the region north and northwest from White Bear lake, extending to Centerville and probably further, and covering Forest Lake and Oneka in Washington county. This was probably a fluctuating lake, thus forming no distinct beaches, yet its outlet a portion of the time of its existence was probably through Big Marine lake toward the south



Julius Bien & Co

and to the St. Croix valley.* The principal drainage into this glacial lake was from a glacier loaded with gray till, since the country it included is now covered by a pebbly, laminated clay, which in some places grades into gray till and in other places is a fine gray clay.

The quarries at Stillwater are the oldest in the Lower Magnesian formation in the state, and furnish an excellent stone for all ordinary buildings and for bridge arches and piers. N. H. W.

*According to report there is such a valley, now abandoned, extending from Forest lake to Big Marine lake, but this has not been verified. This glacial lake is the same as that already designated lake Mahtomedi in connection with the plate of Ramsey county.

PLATE XLV.

CHISAGO, ISANTI AND ANOKA COUNTIES, 1888. WARREN UPHAM.

These counties were originally wooded, but with rather scattering and small trees, amongst which oak and poplar were most numerous. Still, there were tracts of gray till and pebbly clay where the forests were larger. Such tracts are in the southeastern and northwestern portions of Chisago county, the northern towns in Isanti and the western in Anoka counties.

The last act of the glacial epoch in these counties was to spread a vast mantle of gravel and sand, due to the melting of the glacier and the drainage from further north, forming plains similar to the plains mentioned in Washington and Dakota counties. A bayou-like flood of muddy, tumultuous water, partly from the Mississippi valley and partly from the St. Croix, swept over the central part of this district.

At a somewhat later stage the rivers cut into this gravelly expanse, leaving abrupt margins, and still later were again and again reduced. Thus were formed three or more levels of gravel plains, the uppermost and oldest forming the general upland over most of Anoka county, and the others constituting terraces along the rivers. The uppermost terrace in the St. Croix valley is at about 125 feet above the river, in section 2, Shafer.*

Earlier than the formation of this sheet of gravel-and-sand, or, to a large extent, cotemporary with it, the ice-lobe, moving from the northwest, was spread over these counties. The result of its action was to lay down a gray till. This till is distinctly morainic, except in its most eastern portions, where it becomes less stony and might be called pebbly clay. Prior to the spreading of this gray till there had been an interglacial epoch, and the climate had been suited to the growth of forests the remains of which are found in numerous wells in the town of Nessel, north part of Chisago county. Under this interglacial soil, and generally throughout Chisago county under the gray till, is a nearly constant stratum of modified drift derived from the red till, whose manner of origin was probably analogous to that of the gray gravel and sand lying on the gray till, viz.: it was formed by drainage from the ice of an earlier epoch which carried drift from the northeast. This modified red drift is very extensive and spreads through Washington county to St. Paul and into Dakota county. The red till, its source, is equally common, and, as stated in connection with Washington county, constitutes the bulk of the till surface in Washington and Ramsey counties, lying below the modified red drift.

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*The terraces and the general geology of the region of Taylor's Falls have since been the subject of more detailed study by DR. C. P. BERKEY. *American Geologist*, vol. xx, pp. 346-383; vol. xxi, pp. 139-155, 270-294, 1897, 1898.

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In Anoka county cream-colored brick are made from the laminated gray clays derived from the gray till, and red pressed brick from the red clays of the earlier epoch.*

The Keweenawan rocks appear in the valley of the St. Croix river at several places, the most important being at the St. Croix dalles, in the interstate park, at Taylor's Falls. The noncomformable overlying St. Croix sandstone is exposed on section 4, Rushseba, forming a bluff fifty feet high and a quarter of a mile long. The St. Lawrence limestone lies on the trap at Taylor's Falls. N. H. W.

*A glacial lake which may be called lake Shafer covered the eastern part of Chisago county, extending fron Center City to Taylor's Falls.

PLATE XLVI.

BENTON AND SHERBURNE COUNTIES, 1888. WARREN UPHAM.

These counties are covered largely by the deposits of the western lobe of the ice-sheet of Minnesota, either in the form of till or of washed sand and gravel. The former prevails in Benton county and the latter in Sherburne. Still, the till of Benton county has in some places a distinctly reddish hue, showing, apparently, a mixture of the red element with the gray. This red element, combined with absence of limestone boulders, is found in the western part of Benton county. All the morainic patches, and other till of Sherburne county, which rise above the extensive plains and knolls of gravel and sand, are of the gray.

Sherburne county originally was thinly covered by a growth of black and bur oaks, with an undergrowth of oak bushes and hazelnut, but along the streams and in the township of Livonia was heavy timber, while in Benton county heavy timber was spread over most of the county. White pine occurs scatteringly on the bluffs of the Mississippi river, and a few localities northward through these counties, and it becomes abundant, being often the principal forest tree, in the northeast portions of Alberta and Maywood. The tract of land between the Elk and the Mississippi rivers, where they run parallel, was natural prairie. Such prairies also exist in the western two-thirds of Langola, the northwest part of Watab, and in the south part of Minden There is another in the west half of Orrosk.

The only rocks known in these counties are granite and sandstone. The former is well known for the stone suitable for construction obtained at Sauk Rapids and at East St. Cloud, where it has been quarried for many years. The latter occurs in the banks of St. Francis river, in Orrosk, where it rises thirty feet, more or less, above the water, and has been used extensively for construction for many years. Further up this river is a "yellowish limestone" reported. Sandstone also appears in the east bank of the Mississippi river about three miles above Monticello, rising about twenty-five feet above the river. All this sandstone is probably of the St. Croix formation, and it is likely to be found under the most of Sherburne county. N. H. W.

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PLATE XLVII.

STEARNS COUNTY, 1888. WARREN UPHAM.

The Archean rocks noted in connection with Benton and Sherburne counties (Plate XLVI) continue westward and extend everywhere under Stearns county. They appear in outcrop in Ashley, in the extreme northwest and in Saint Augusta in the southeastern town of the county, also at many intermediate points. These rocks, as exposed, are chiefly granite, syenyte, dioryte, with a little mica schist.* It is highly probable that if the drift could be removed the schists would be found much more common. Their more destructible nature has caused them to be decayed and eroded. They therefore are most likely to occupy the depressions in the preglacial surface, and these depressions are also the places where the drift deposits were most likely to be left, whether by the ice or by the floods of the glacial epoch.

At several places in Stearns county these rocks are wrought for use in all places in which granite is applicable. The quality of some of these granites has been given in volume I, in the chapter devoted to the building stones of the state.

The drift features of this county are quite complex. The northwestern and northeastern ice-lobes of the last glacial epoch appear to have occupied this area sometimes jointly and in some places alternatingly. The drift of the earlier glacial epoch has not been satisfactorily differentiated from that of the later. Belts of morainic drift run somewhat irregularly through Stearns county. These probably are in part medial moraines and in part terminal, and all of them belong to the last glacial epoch. The east half of the county, speaking generally, is characterized by the northeastern drift and the west half by the northwestern; but in some places the color and characters of the northeastern have in a measure faded out. There was, further, a later advance of the northwestern ice further east, even as far as the Wisconsin boundary, and the retreat of this ice-lobe left a large amount of northwestern till and gravel and sand, much further east than the centre of the county. This is continuous with similar deposits mentioned in Wright, Benton and Chisago counties. These later deposits uniformly lie upon red drift from the northeast.

It was at a still later date that a glacial river of considerable size, now dried up, flowed across Stearns county, as mentioned in the description of the plate of Kandiyohi and Meeker counties, draining from the still existing ice-fields of the counties further northwest. Its abandoned valley lies in Zion, Munson, Wakefield

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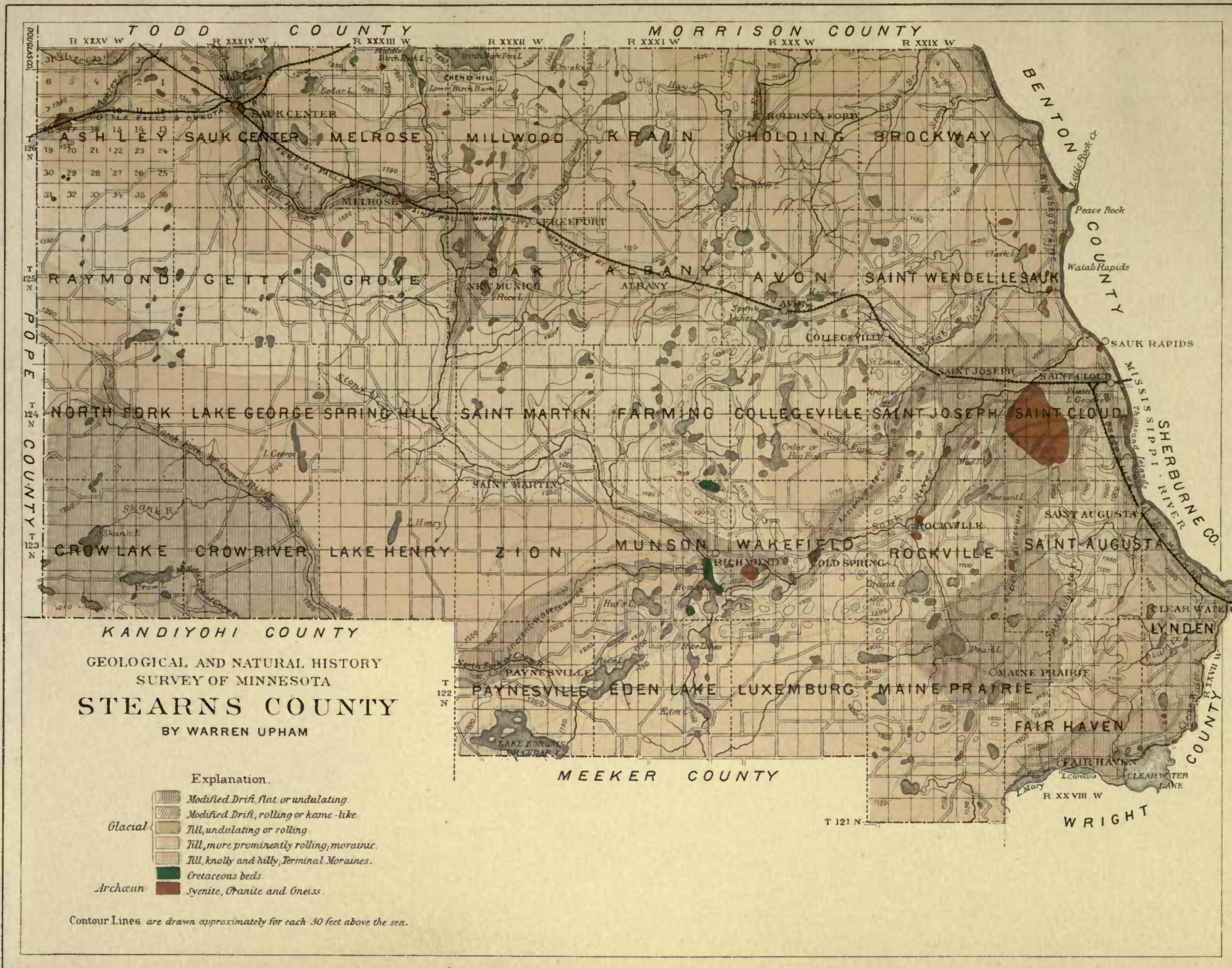
*Detailed descriptions of the rocks at Watab, Sauk Rapids and Sauk Center will be found in the *Eleventh Annual Report*, 1883, p. 71. Observations on the field relations made at Sauk Center are published in the *Thirteenth Annual Report*, 1884, p. 11. Rocks collected at Sauk Center are described also in vol. v, pp. 566, 574. The St. Cloud granites are described in vol. v, pp. 550-552; 564, 838.



Julius Bien & Co. lith.

and St. Joseph townships. Another similar valley enters Stearns county from Pope county in the town of Ashley and unites with the Sauk River valley.

The Cretaceous ocean also appears to have covered this county, and its sedimentary deposits in the form of kaolinic and lignitic clays are found near Richmond, in Munson township. N. H. W.

PLATE XLVIII.

DOUGLAS AND POPE COUNTIES, 1888. WARREN UPHAM.

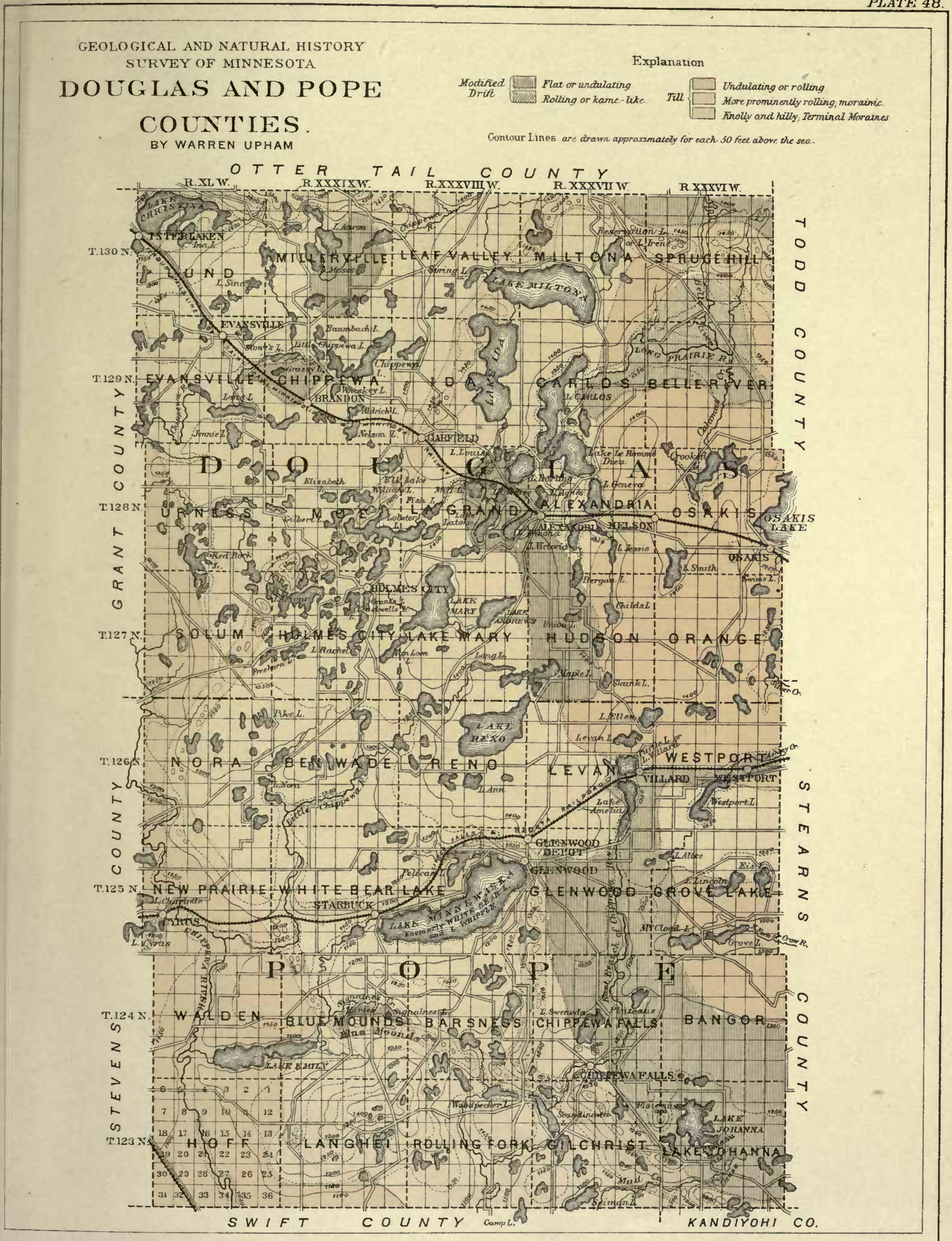
These counties do not afford a single known outcrop of the underlying rock. There is no reason to doubt, however, that the formations of Stearns and Todd counties, the Archean and the Cretaceous, extend westward under these counties.

The drift features are therefore the only geological phenomena that need be mentioned. An extensive morainic belt runs north and south through these counties. It is about twelve miles wide. On the west this rolling belt is bounded by the nearly level till expanse of Grant and Stevens counties, which slopes gently toward the Red River of the North or to the valley of the Minnesota. On the east of this rolling tract are gravel plains which extend into Stearns and Todd counties. In the midst of these gravel plains are considerable areas of more nearly flat surface composed apparently of till, and others also in which the morainic features of the main morainic belt extend eastward.

Crossing this morainic belt from the region of the Leaf hills, in Otter Tail county, is a remarkable narrow series of more pronounced drift ridges which need special mention. This series first runs southwestward through Douglas county, then southeastward through Pope, entering Kandiyohi county, where it turns east and is apparently joined north of Green lake by another range which runs northeast. It then seems to fade away in the general gravelly plain which extends from Kandiyohi county into Stearns county, from which an ancient water-course is traceable entirely across Stearns county in a northeasterly direction to St. Cloud, uniting there with the high gravel plain which forms the highest gravel flat of the Mississippi.

This series of gravelly hills and ridges has received different interpretations. By Mr. Upham, who is more familiar with it than any other person, it is considered a special morainic ridge or series of ridges, formed by ice moving outwardly from the general glacier that occupied the Red River valley. There is, however, some reason to consider it a monstrous kame, or series of kames, formed by a great river which, at its source, was constantly in the ice field and received the drift which it washed, directly from the ice. As the ice retreated the source retreated, but the course of the river, once established by the removal of a large amount of the drift, occupied the same position in its lower reaches as was determined by the drainage while the ice was present. The lower part of this water-course was therefore the oldest and was modified by the incidents of the river during the floods that were later. Whereas, the gravel near its source was laid down in kames, in the lower reaches its gravel was spread over alluvial plains and buried or obliterated the original kames;

PLATE 48.



Julius Bien & Co. lith.

but further toward the place of the latest remnant of the glacier these original kames become more and more distinct. It is hard to understand how, under the theory of the ice origin of these ridges, they should show the following characteristics:

1. From Otter Tail county the level of the base of this series descends and never ascends, *i. e.*, where the series enters Douglas county, in Miltona, it is on the contour of 1,450 feet; at a mile and a half north of Garfield it is at 1,450 feet; at the west end of Lobster lake, in Moe, it is at 1,400 feet; at the west end of lake Oscar 1,400 feet; in section 3, Nora, 1,350 feet; in section 30, White Bear lake, 1,200 feet; at the Blue Mounds, 1,200 feet; in section 34, Barsness, 1,200 feet; section 23, Gilchrist, 1,200 feet; Norway Lake, 1,200 feet to 1,250 feet; New London, 1,200 feet; Roseville, the general gravelly plain, 1,200 feet; Zion, Stearns county, bottom of the ancient water-course, 1,150 feet; Richmond 1,100 feet; St. Joseph 1,050 feet; St. Cloud 1,000 feet. There are minor irregularities in this steady descent which may be attributed either to modification of the contours by subsequent drainage, or to slight error in the contour lines as drawn on the county maps.

2. Why this belt twice crosses obliquely the main morainic belt of the region, and in opposite directions.

3. Why the series is so narrow.

4. Why the direction changed 90° within the limits of Pope county.

5. Why, in any place, these deposits should take on the characters of a kame, consisting of one or more long, parallel, gravel ridges, as they do in Blue Mounds and Barsness, unless there had been a large glacial river flowing at the time of deposition, in the direction of these ridges.

6. If such a river formed the gigantic kame at Blue Mounds and in Barsness, why its further effects cannot be seen.

7. Why should the main ridge, which is of gravel and sand in Blue Mounds and Barsness,* be bordered by a valley on either side, the outer bluffs of which consist distinctively of till with a smooth or undulating upper contour, rising abruptly 50 to 100 feet above these valleys?

These features are all explainable on the supposition that the copious southward drainage from the interlobate area, where now the Leaf hills lie, dammed out of the Red River valley by the tongue of ice that lingered there, was gathered into a large river which flowed southward along the eastern margin of that tongue of ice until, guided in the main by an older glacial valley, it was carried eastward to the Mississippi.

N. H. W.

*The writer has examined this ridge only at Blue Mounds and in Barsness. See *Thirteenth Annual Report*, pp. 17-19, 1884.

PLATE XLIX.

GRANT AND STEVENS COUNTIES, 1888. WARREN UPHAM.

These counties extend, in an east and west direction, from the broad, flat expanse of the glacial lake Agassiz on the west to the morainic hills which diversify Douglas and Otter Tail counties on the east. The hilly tract barely enters Grant county in the northeastern township, where it is well developed on the south and west sides of Pelican lake, and especially on the north side. Broad till undulations characterize, also the southeastern township of Stevens county. These counties are wholly prairie, with timber only in small groves in the vicinity of some of the lakes and along the streams.

These counties contain no rock outcrop, and the drift sheet would average perhaps 150 feet in thickness. Under the drift the Archean rocks probably exist, perhaps with scattered areas of Cretaceous.

The two uppermost shores of lake Agassiz enter the western limits of these counties, *i. e.*, the Herman and the Norcross beaches. The former has an average elevation of 1,050 feet at lake Traverse, but rising toward the north so as to reach 1,065 to 1,075 feet in northern Grant county. The latter is about thirty feet lower. These beaches consist of gravel and sand, descending westwardly to a flat or nearly flat expanse of till which is sometimes indistinctly stratified, about eight or ten feet, and eastwardly somewhat less to a nearly equally uniform expanse of till.

The deep well at Herman passed through 124 feet of till, striking granitic rocks under a mass of limestone boulders. Water rose within four feet of the surface. The total depth of the well is 260 feet. N. H. W.

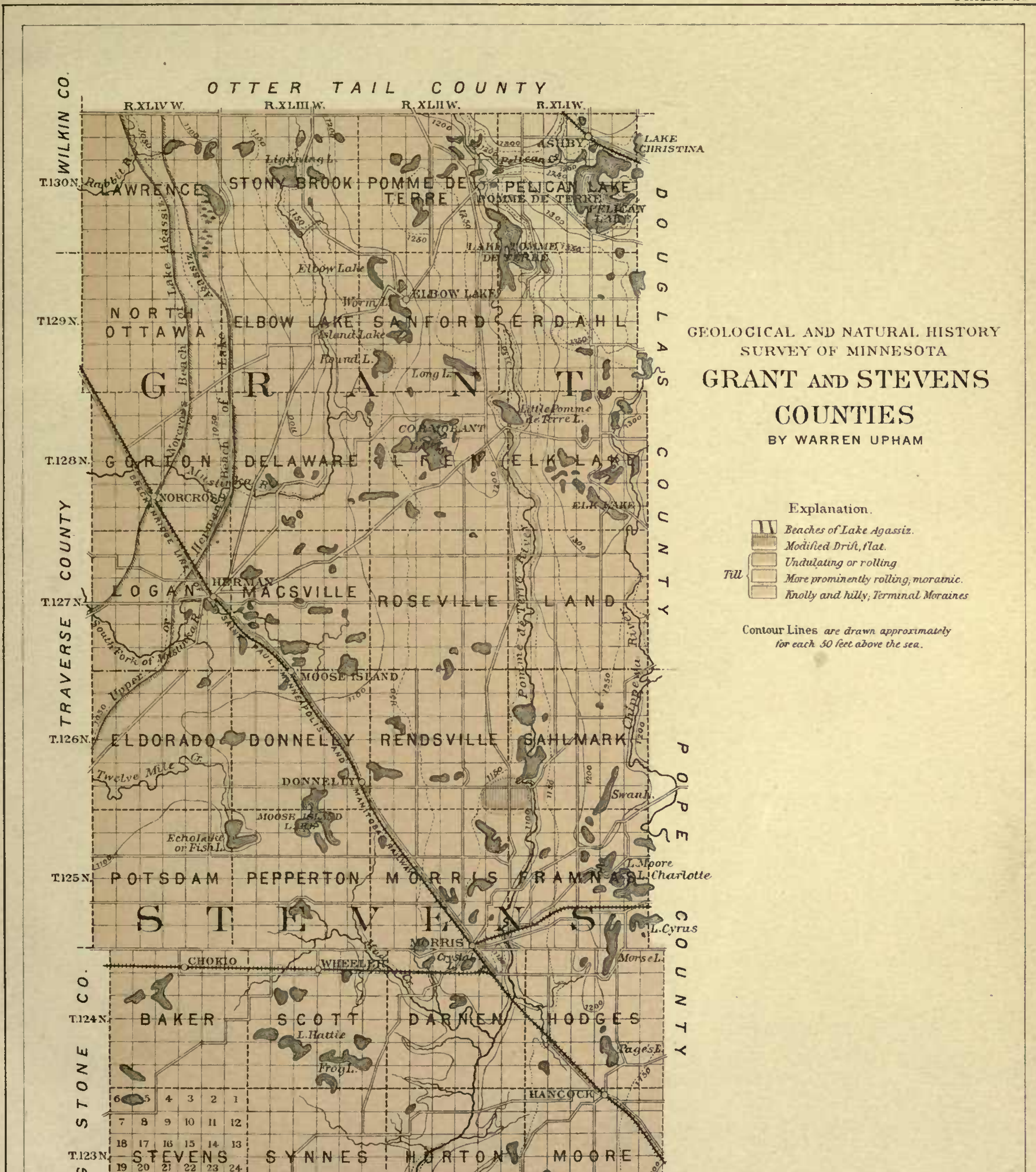


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PLATE L.

WILKIN AND TRAVERSE COUNTIES, 1888. WARREN UPHAM.

These counties are wholly without exposures of the underlying rock, and the drift surface is monotonous. Within the area of glacial lake Agassiz the surface is flat or so nearly flat that it is only at long distances that any change of altitude can be detected. Outside of the beaches of lake Agassiz the surface is but little more undulating. Into this very uniform prairie surface the main streams have excavated sharply bluff-lined valleys. These are the Red River of the North and the Bois des Sioux, with its southern extension to lake Traverse, whose bluffs are from twenty to forty feet high. The bluffs along lake Traverse, on each side, are composed, so far as known, of till, and rise from 100 to 150 feet above the lake, being highest along the southwest part of the lake. These continue on each side of Brown's valley to Big Stone lake, having about the same hight; thus there is plainly an ancient water-course, once occupied by a large river, connecting the valley of the Bois des Sioux with the valley of the Minnesota. This valley was the way of discharge of lake Agassiz until, by the retreat of the glacier, it found a lower outlet toward the north.

The beaches of lake Agassiz consist of gravel and sand in the form of continuous, smoothly-rounded ridges, rising from three to ten feet above the land on the east, and from ten to twenty feet above that on the west. These beaches vary from ten to twenty-five or thirty rods in width, constituting broad, wave-like swells with a smooth, gracefully-rounded surface. They are but seldom interrupted by unfavorable conformation of the original shore line, or by subsequent removal by streams, and have been traced continuously for a distance of 175 miles in the state of Minnesota. They also exist in Dakota, and run into Manitoba. These beaches, in descending order, have been named Herman, Norcross, Campbell and McCauleyville. The till on which they lie is usually of the ordinary kind, but occasionally shows stratification. This till furnished the gravelly material of the beaches under the action of waves. It also supplied that of some stratified clay which sank in the deeper part of the lake. Such clay, however, is not widely spread, but is confined essentially to the central depression of the Red River valley. This restriction of these clays seems to show, according to Mr. Upham, that they originated, not during the existence of lake Agassiz, but at a later extended fluvial epoch by streams that flooded the valley with muddy water, carrying occasional vegetation.

The Herman beach is eighty feet above lake Traverse.

The Norcross beach is twenty-five feet lower.

The Campbell beach is fifty feet still lower.

The McCauleyville beach is ten feet lower than lake Traverse.

Julius Bien & Co. lith.

At the time of the McCauleyville beach the outflowing river Warren had a level about the same as that of the present bed of lake Traverse. These beaches ascend toward the north, the Herman beach at the rate of 125 feet in 142 miles, the lower beaches at a less rate. This shows that the land toward the north has risen since the beaches were formed. This lake was larger than lake Superior, and its surface was 200 feet above the lake of the Woods and 700 feet above lake Winnipeg.

N. H. W.

PLATE LI.

OTTER TAIL COUNTY, 1888. WARREN UPHAM.

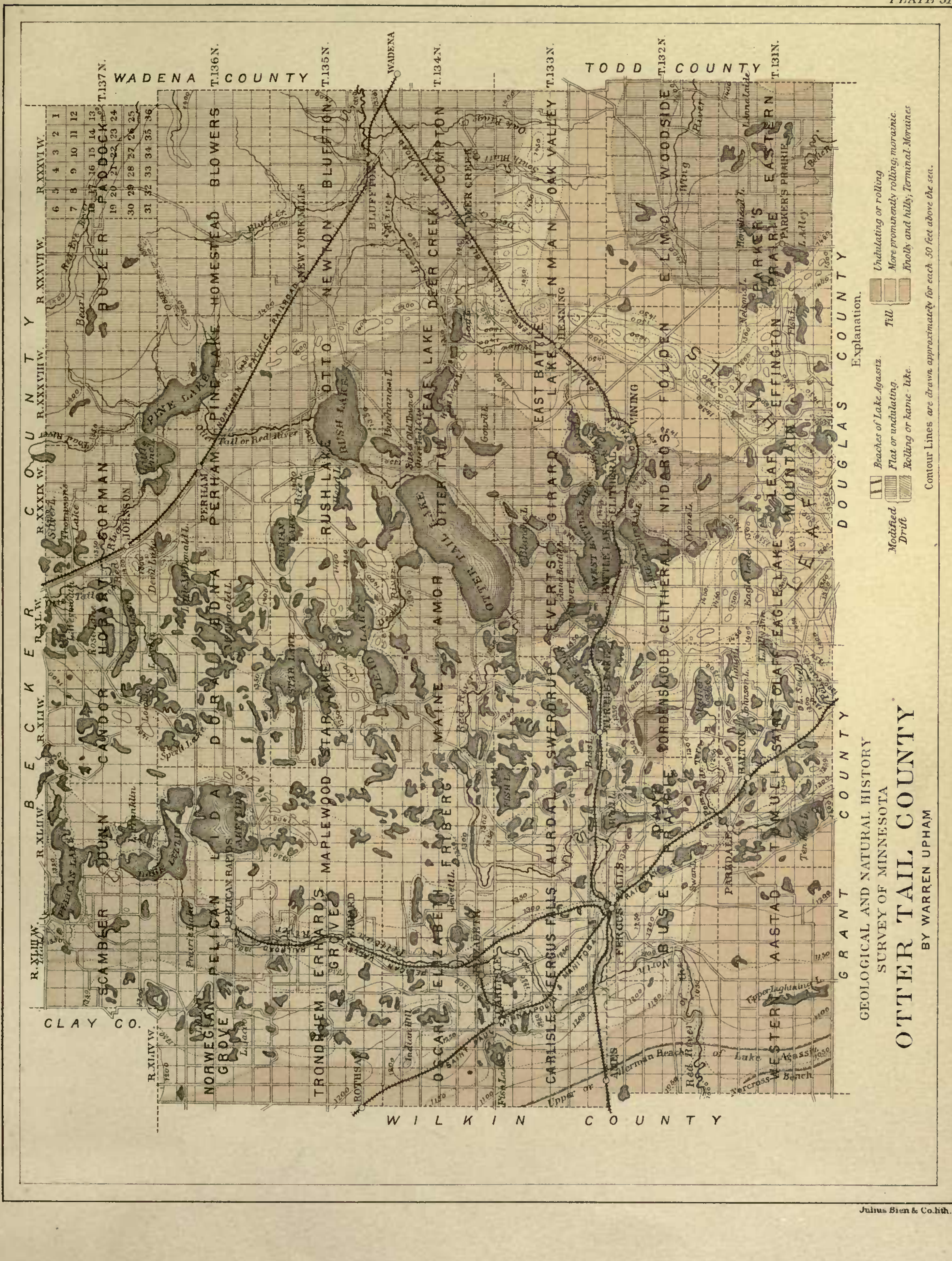
With no rock outcrops, this county is about two-thirds covered by timber, the prairie region being in the west. There is also a sprinkling of prairie patches through the rest of the county, and especially in a belt which extends north and south across the central portion of the county.

According to Mr. Upham's mapping three chief morainic belts converge southward to the Leaf hills, which are near the centre of the south boundary of the county. The western belt, in its southern part, consists of three parts or series of ridges elongated about north and south, this triple composition being most conspicuous south of the latitude of Fergus Falls, yet traceable indistinctly through the central and northern parts of the county, with interruptions. The central belt is less continuous and blends with the eastern portion of the western belt. The eastern belt is narrow and quite persistent and distinct, running from Pine lake southward, with a curvature toward the east, to the Leaf hills. Indeed, this belt is called Leaf hills southward from the Leaf lakes. While this description covers the greater part of the morainic areas, yet there is a spur running eastward through Inman and Oak Valley into Todd county, and another southeastward into Douglas county through Effington and the southwestern part of Parker's Prairie.

Large areas in the central and eastern portions of the county are composed of modified drift, usually flat, but sometimes in rolling or hilly contour. The rolling tracts of modified drift are sometimes marginal portions of moraines, or are in the form of fringes or bands that lie between the moraines and the gravelly plains.

This county has, by actual count, 1,029 lakes, not including sloughs and ponds, the largest being Otter Tail lake, eight miles long and two and a half in width, lying in a flat country of gravel and sand. The water area of the county is given at 162,749.67 acres. In this county the Leaf river, also the Crow Wing, the Pomme de Terre, the Chippewa and the Long Prairie take their source, while the Otter Tail, or Red River of the North, flows across the county from northeast to southwest, taking the surplus waters of most of its lakes. This last stream is entirely a post-glacial one, having taken its tortuous course amongst the hills of the region since the departure of the ice, and probably since the withdrawal of lake Agassiz, since it formed no delta deposits in that lake.

This county embraces the heart of the "Park Region" of the state, a designation which is very appropriate, and is due to the beauty of landscape, the diversity of land and water, the hilly contour, the irregular distribution of the forest and prairie areas, the abundance of game and the salubrity of the summer climate. N. H. W.



Julius Bien & Co. lith.

PLATE LII.

WADENA AND TODD COUNTIES, 1888. WARREN UPHAM.

There are two points in Todd county, in the valley of the Long Prairie river, at which the crystalline rocks appear at the surface. One is in Ward township and the other in Villard. But in Wadena county the underlying rock never appears above the drift surface. The outcrop in Villard is a form of gabbro that has somewhat the appearance of dioryte, as well as its composition. This alteration is due apparently to dynamic action in part, since augite is found preserved (No. 1685A), and since the rock at the lumber dam (No. 1687) has the vertical attitude and structure of coarse slates as if at a contact plane where friction and pressure had been powerful. Where this rock is greatly saussuritized it is nearly white (as at the old quarry), the whole consisting very largely of zoisite. This rock may belong to the Archean, but it resembles some phases of the gabbro of the Taconic.

The rock in Ward is quite different and undoubtedly belongs to the Archean. It forms a ridge about eight feet high, twenty rods long, extending northwest and northeast, with a width of three or four rods. It is a light-colored, greenish and grayish syenyte, the light-green color being due to epidote. It is not schistose, but is intersected by joints, and could be quarried to advantage for building stone for the neighborhood.

Wadena county is wholly covered by modified drift in the form of a plain, which undulates but little from a flat.

Todd county is divided between till and modified drift, the greater portion being modified drift. The central portion of Todd county is covered by smooth or undulating till, but the main streams are accompanied by narrow belts of gravel and sand. Till is found largely in the moraines in southern and eastern Todd county. This till is probably 100 to 150 feet thick and came largely from the northwest, judging from the abundance of limestone in the gravel. Boulders of limestone are not common on the surface except in the southwestern part of the county, where they constitute from one-tenth to one-twentieth part of the superficial boulders. The last movement of drift seems to have been from the northeast.

The forms and distribution of the moraines, as well as their composition, in in Todd county, will not warrant, with the study that has been given to them, positive statements as to the changes of the glacier during the Glacial epoch. N. H. W.

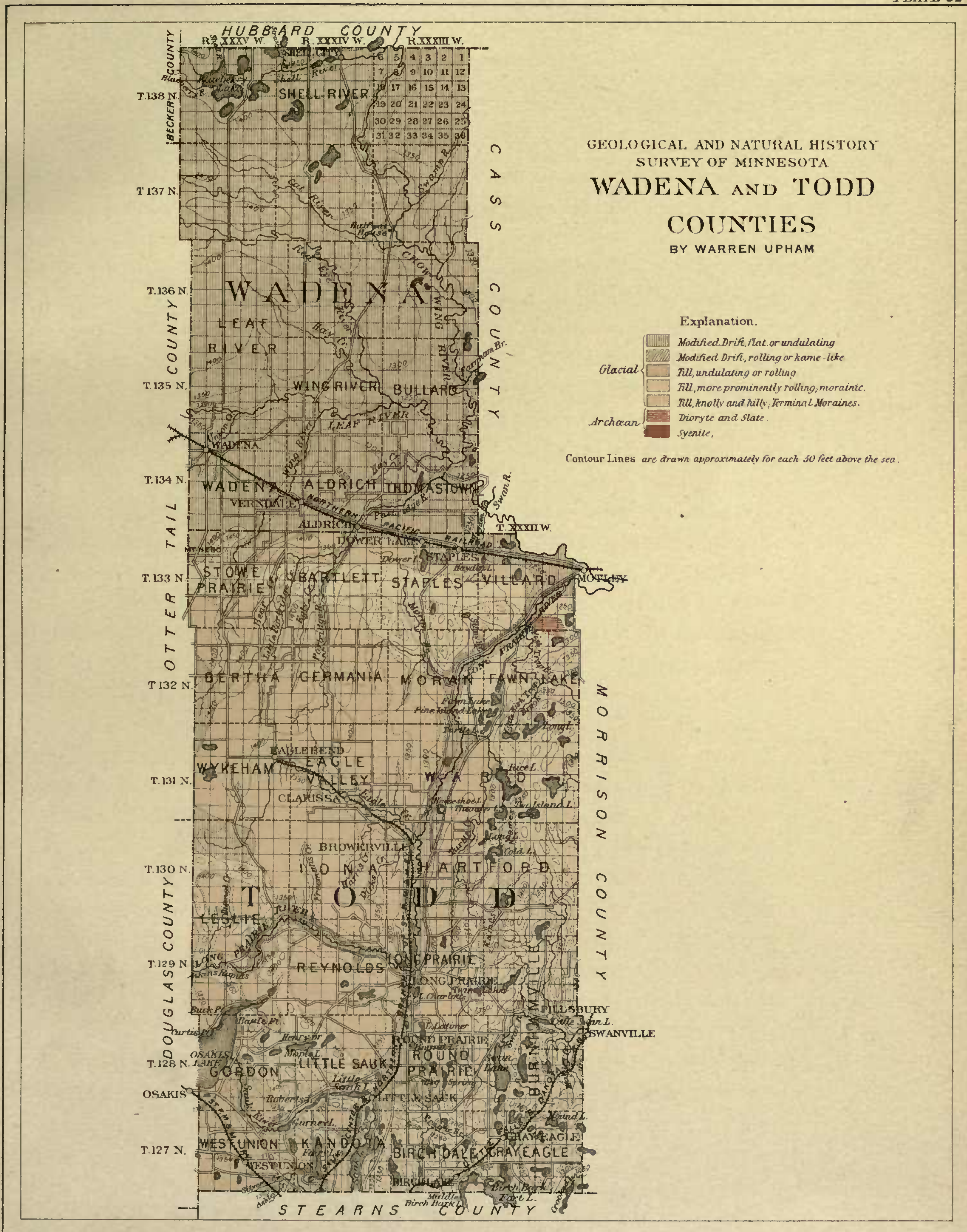


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PLATE LIII.

CROW WING AND MORRISON COUNTIES, 1888. WARREN UPHAM.

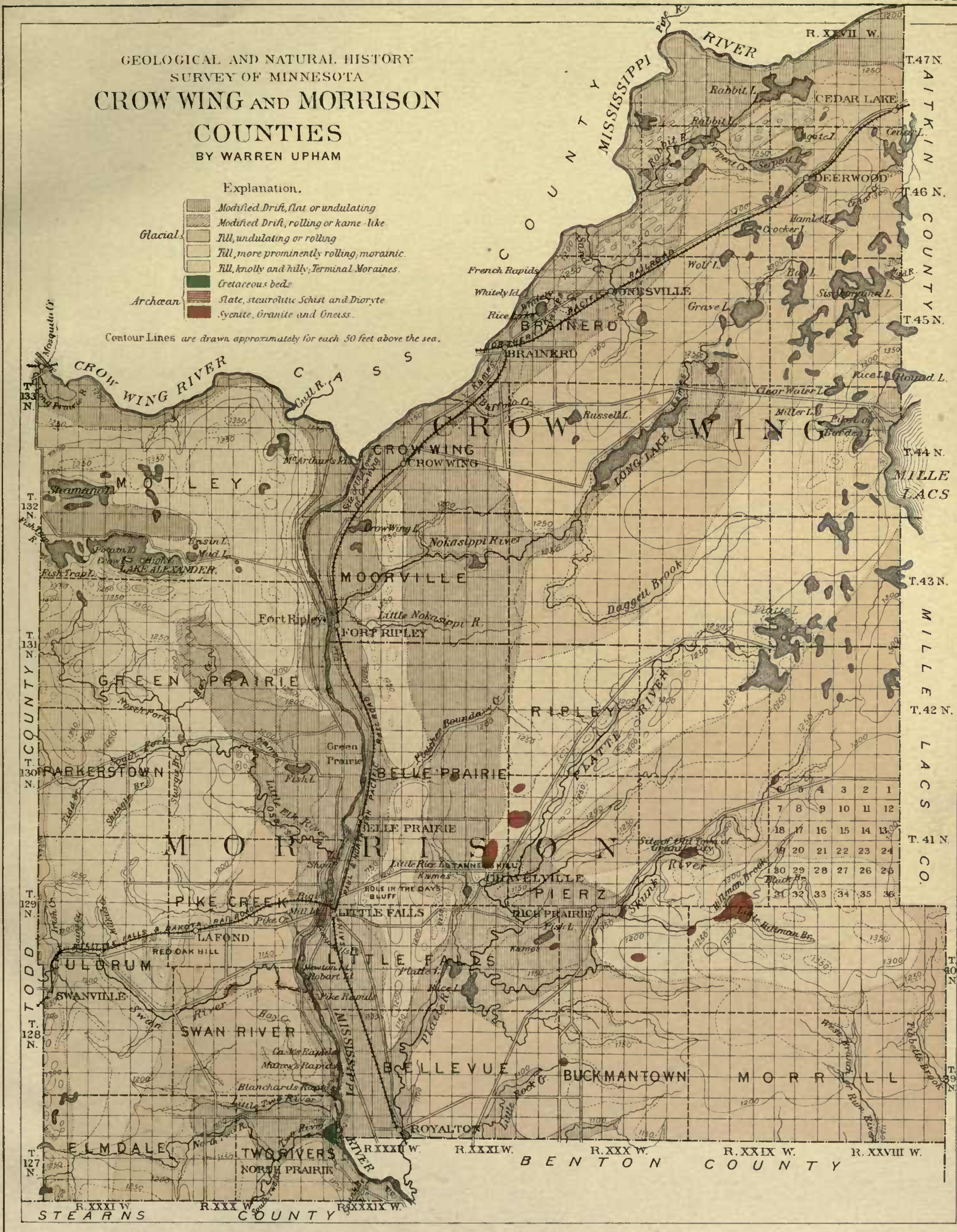
Crow Wing county has no rock outcrops, but Morrison has many. The oldest are the greenstones seen in the northwestern part of Morrison county, cut by the railroad at Randall station (sec. 7; T. 130–30). It is a fragmental rock, appearing somewhat conglomeratic (No. 1677). Between this and the granites of the eastern part of the county are mica schists, as seen at Little Falls and at Pike Rapids, and on the Mississippi below Pike Rapids. These mica schists are due to metamorphism of rocks like the greenstone seen at Randall, or other fragmental strata associated with them. These schists are garnetiferous wherever seen in Morrison county, and at Pike Rapids they are conspicuously staurolitic. They are, in some places, quite fitted for building stone, being fine grained, homogeneous and of a light-gray color.

In the midst of the staurolitic mica schists, at a point a short distance below the mouth of Swan river, and where the principal rock reef causing the principal water-fall crosses the river, is a marble-like layer of limestone, standing several feet above the water, rather poorly exposed, seen on the west bank. It is pinkish and fine grained, and marked apparently with a sedimentary structure which coincides in direction and dip with the principal structure of the staurolitic schists of the place.

Accompanying the metamorphism of the clastic strata of the Archean much granitic rock was formed. This is found in most of that part of Morrison county east of the Mississippi river, extending in a belt eastward from Little Falls. It extends from Belle Prairie to Buckmantown, in a north and south direction, and in an east and west direction nearly to the eastern line of the county. It is also quite certain that it is a part of the granite seen at Mille Lacs. This granite is of later date than the schists, being intrusive in the schists.

At about two miles west-northwest from Little Falls is a rock that may be younger than the granite. It is gabbro (No. 1678) similar to that seen at Duluth, but sometimes it is hornblendic, constituting a dioryte rather than gabbro.

The youngest rock in the county is of the Cretaceous, seen at the mouth of Two rivers, but probably extending under the drift over most of the southern part of the county. In this Cretaceous have been found *Margaritana* and *Unio*, also a shark's tooth. These shales are lignitic and are referred to the later part of the Cretaceous. They contain evidently a large proportion of kaolinic clay derived from the pre-glacial decay of the Archean. Analysis showed 19.81 per cent of silica and 52.43 per cent of alumina. This substance would probably make fire-brick. Its hardness is but little less than that of limestone.



Julius Bien & Co. lith.

The glacial deposits show gravel plains along the Mississippi river formed by drainage which converged from the northwest and northeast in the later part of the ice age. Some of the old glacial streams, existing while the ice was on the ground and confined by it between walls of ice, seem to be indicated by the kame-like ridges seen in Ripley, along the Platte valley, and by those that exist southeastwardly from lake Alexander.

Most of the drift seen at the surface in these counties came from the northeast. It is characterized by numerous boulders, many of which are of the green, gray and red igneous rocks of the region of lake Superior. The till of the southwestern portion of Morrison county, including three or four towns, and much of the gravel of the western part of the county carried eastward by the glacial drainage, partake of the characters of the gray till.

These counties are well supplied with timber and with water-power. They have clay for brick and abundant stone for construction. The brick clay at a mile northeast from Brainerd, making a cream-colored brick, is extensive, having been found by borings, for nearly a mile along the river, with a width of half a mile.

Quartz chippings, made by aboriginal man, are abundant in the surface loam at Little Falls. It is still unsettled whether these chippings are wholly post-glacial or coeval with the departure of the ice. They may be as late as the present Indians, since such quartz arrow-points occur at Mille Lacs amongst the debris left by the Issati Sioux. N. H. W.

PLATE LIV.

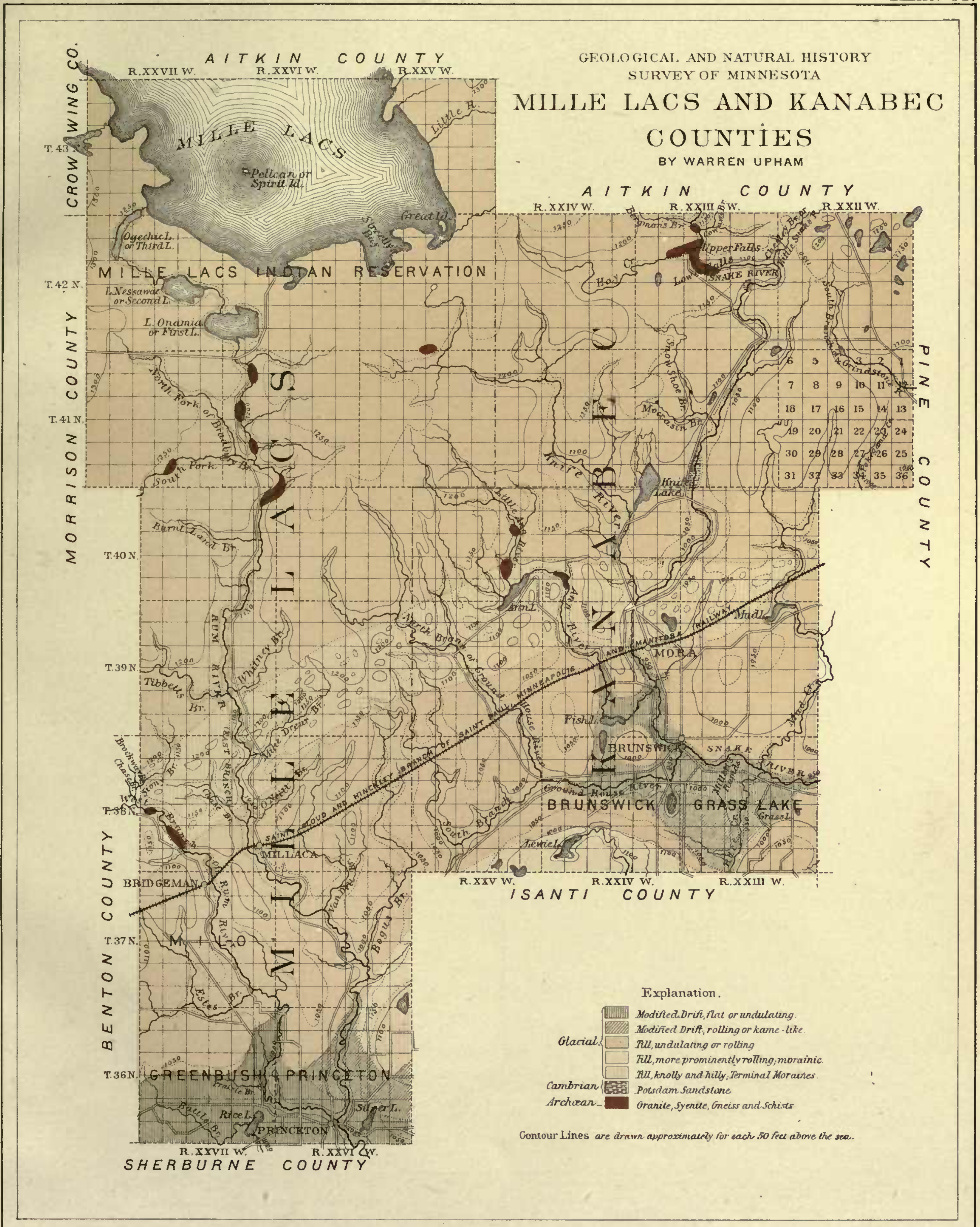
MILLE LACS AND KANABEC COUNTIES, 1888. WARREN UPHAM.

The old route of the Issati from the Mississippi, Rum river, drains Mille Lacs county, and that from the St. Croix, Serpent river, drains Kanabec county.

The surface of these counties is seldom rough, the most broken part being a low morainic belt that enters from Benton county and extends across both counties in an east-northeast direction, having a width of about four miles. This is frequently composed of coarse gravel and sand with boulders. It is a singular fact that, as represented by Mr. Upham, it is crossed nearly perpendicularly by the principal streams of the county, as well as by many of the subordinate streams, without apparent deflection or derangement of any kind. Most of these counties are underlain by till, with many boulders from the northeastward, the only northwestern drift being in the southern part of Mille Lacs county.

Granitic rock appears in outcrop at numerous places along the valley of the Rum river, the Ann river and of Snake river, the last being at the upper and lower falls, not far south of the Aitkin county line. On the west branch of Rum river this granite is coarse grained and reddish, without much lithological variation, apparently an extension of that seen in the eastern part of Benton and Morrison counties. In Kanabec county, and especially at the upper and lower falls of Snake river, the granite is gray, rather fine grained, intersheeted with mica schist and much contorted, being apparently a gneiss resulting from metamorphism. It is also associated with considerable amounts of coarse pegmatyte.

Unconformable over these rocks is a dark-red sandstone, which is in part conglomeritic, belonging to the Potsdam, which is quite similar to the sandrock and shales seen at Fond du Lac in Carlton county. This is seen in outcrop a few miles southeast of the lower falls of Snake river, and at the south side of T. 41–23 along the banks of the same river, showing a dip E. N. E., which in extreme amounts to 20°. In the south part of T. 41–23 similar red sandstone is exposed in the banks of the Snake river, affording a thickness of twenty-five feet, alternating with ash-colored clays. About six miles further south and three miles west, sandstone of coarse grain and gray or iron-rusted color appears in the right shore of the same river 300 feet in length, with a width of seventy-five feet. It has a variable eastward dip, the steepest being 15° E. S. E. This rock is somewhat pebbly with quartz pebbles up to three and a half inches in diameter, but has not the character of an ordinary conglomerate. Some layers are of a dull red color. A well at Milaca struck sandstone.



Julius Bien & Co. lith.

These counties have a fertile soil. They were originally occupied more or less by white, red and jack pine, excepting only Greenbush and a part of Milo in the southwest. Great quantities of pine have been cut from the region along all the streams of these counties. Mingled with the pine is a great variety of deciduous trees common in this latitude further west. N. H. W.

PLATE LV.

PINE COUNTY, 1888. WARREN UPHAM.

The Archean is found in the northwestern corner of this county, but wholly west of Kettle river. It consists of mica schist, often conspicuously veined with white quartz, rising in rough knobs forty to seventy-five feet high. This is west and northwest from Sturgeon Lake station. About ten miles further southwest, namely, in the southeast corner of sec. 30, T. 44–21, is found a gneissoid granite. This also appears in the north part of section 29, while, within half a mile still further northeast, in the valley of the creek, is sandstone. It is evident that there is an overlapping nonconformity of the latter upon the Archean. The sandstone is probably the same as that seen at Hinckley and widely in the Kettle River valley, supposed to belong to the Upper Cambrian. The same sandstone is seen in the Little Willow river, secs. 1 and 2, T. 44–19, extending half a mile, rising ten feet above the river. This sandstone forms almost continuous exposure along the Kettle river from the north line of town 43 to within two miles of the southern line of town 41, where it is abruptly replaced by trap for an interval of about two miles. It reappears, however, in town 40, and also along the St. Croix river in Chengwatana and Pine City townships. It has been called the Hinckley sandstone, from Hinckley, in this county, where it was formerly quarried. It overlies the traps nonconformably but underlies conformably the sandstone and impure limestone which themselves come upon the the trap at Taylor's Falls. This shows a gradual sinking of the region below the ocean during the accumulation of the Hinckley and St. Croix sandstones, which was earliest, and probably greatest, toward the north. Whether the trap seen on the Snake river at Chengwatana and on the Kettle river at its union with the St. Croix, dipping eastwardly, belongs to the eruptive epoch of the Cabotian or the Manitou, is not known.

This trap, with its surface amygdaloids and its conglomerates of red felsyte and quartz-porphyry,* is very thick, containing traces of metallic copper, and most probably belongs to the series that appears at Duluth and eastward, which is Cabotian, *i. e.*, it is probably older than the Puckwunge conglomerate, and is represented in the section at Duluth by No. 4 of the summary statement of the Short Line Park deep well, page 570 of volume IV. It is also probable that the Hinckley sandstone, at points further east and northeast, where locally the traps are wanting, passes conformably downward into the red sandstones of Fond du Lac, which are interbedded with much red shale. Such shale is the effect of cotemporary volcanic eruption of the Manitou igneous epoch.

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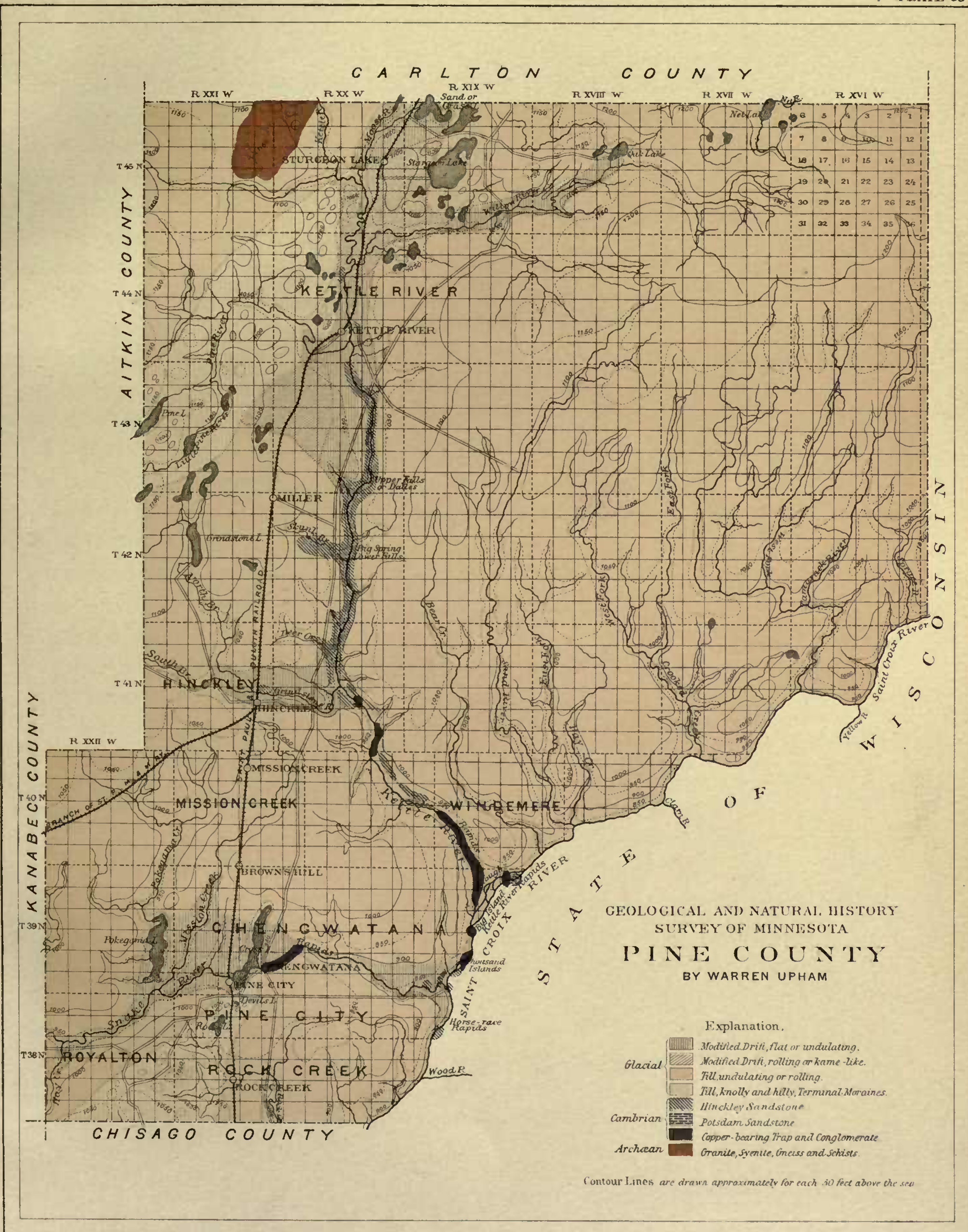
*The most northern point at which these rocks are known in this county is in the north part of sec. 25, T. 45–17, nearly on the divide between the highest sources of the Willow river and the Nemadji.



Julius Bien & Co. lith

The drift in the main was derived from the region to the northeastward. It is less thick than in most of the country to the west, averaging about seventy-five feet. But south of Snake river the drift contains limestone boulders and gravel, evidently from the west or northwest. A distinctly morainic tract about six miles wide enters the county from Chisago county, and another from Aitkin county of about the same width. These drift materials were washed by the waters resulting immediately from the glacier and gave rise to copious gravel products which were strewn over the country toward the south from the ice along the main valleys, forming delta plains, which, cut into by the post glacial drainage courses, have formed the terraces that bound most of the valleys.

The Kettle River valley was, later, the outlet of lakes St. Louis and Nemadji, glacial lakes that were in Carlton county at the western end of the Lake Superior valley; while at a still later date a larger glacial lake, occupying the western end of the Lake Superior valley, had its outlet by way of the Brulé-St. Croix valley through Wisconsin. It is probable that the most of the post-glacial excavation in the rocks, seen along the Kettle and the St. Croix rivers, was due to these larger streams.

Owing to the finding of many nuggets of native copper in Pine county it is probable that the Keweenawan rocks will be found to contain copper in considerable quantity, but all mining tests that have been made to discover such deposits have thus far proved unsuccessful.

The Hinckley sandstone is extensively qnarried in the bluffs of Kettle river.

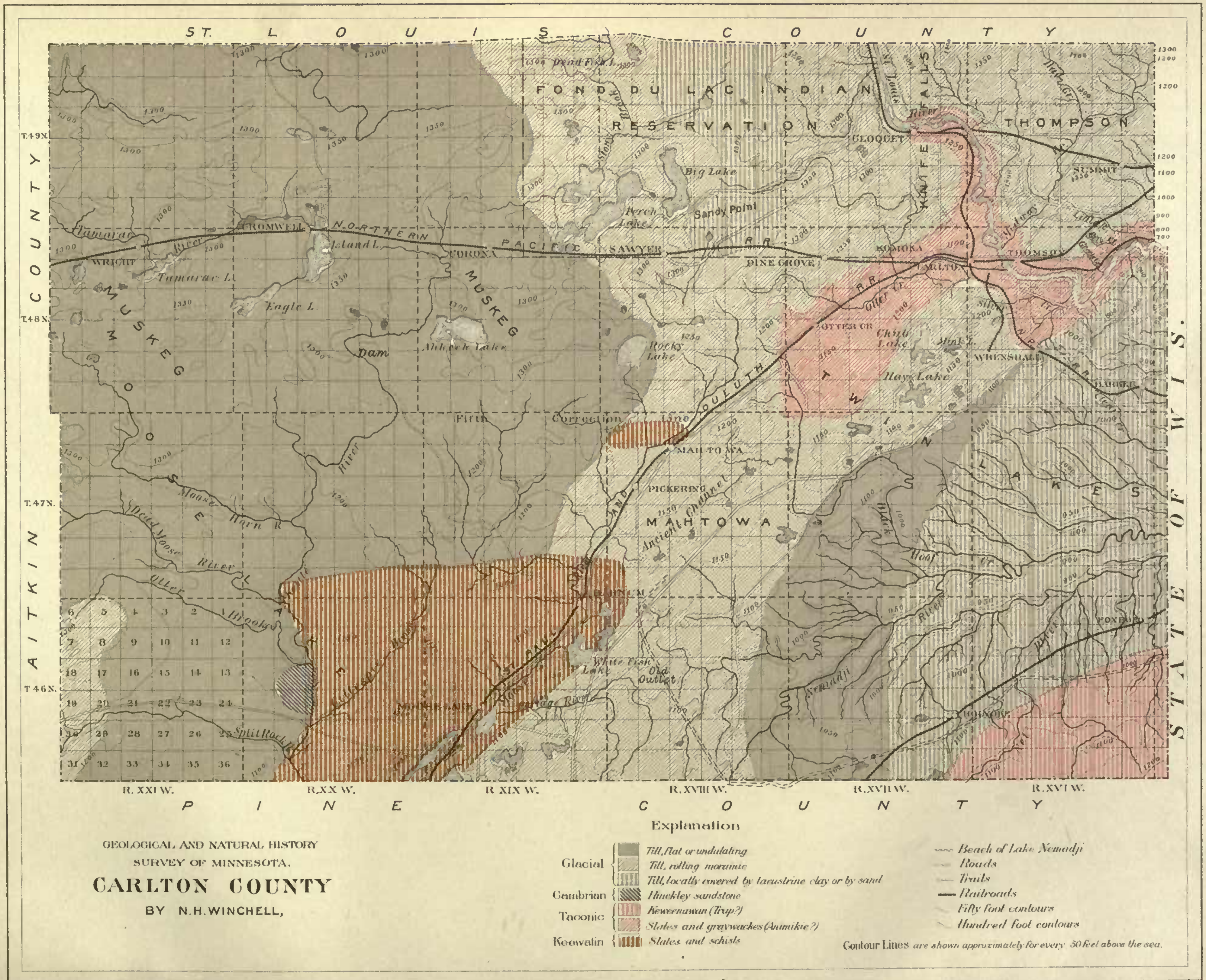
N. H. W.

PLATE LVI.

CARLTON COUNTY, 1899. N. H. WINCHELL.

The Archean (Keewatin) appears in the central and western portions of this county. It is in a sub-crystalline condition, and is correctly denominated mica schist throughout a large part of its area. In that condition it is accompanied by numerous veins and lenticular masses of white quartz, and by pyrite which in some cases has been somewhat exploited for gold, but with poor success. The crystalline condition fades out more and more, and the usual lithology of the clastic greenstones of the Lower Keewatin can be fully identified at points a few miles west from Mahtowa; while from Barnum and Moose Lake westward to the Kettle river the underlying rocks are chiefly fine mica schists, with some indications of Cretaceous. There is no known granite in Carlton county, but it can be at no great distance away toward the west or southwest, judging from the prevalence of metamorphic rocks in that part of the county. The Animikie overlies nonconformably the Archean, but owing to the thickness of the drift and the similarity of the Keewatin to the tilted Animikie the line of strike of the base of the Animikie has never been clearly defined. The quartzyte and taconyte, which are at the bottom of the Animikie along the Mesabi range, have not been discovered in Carlton county, although the quartzyte has been doubtfully identified in Aitkin county and probably exists in Carlton. The slates at Carlton and along the St. Louis river to Cloquet and the slate seen at the railroad cuts southeastward from Carlton are here classed as Animikie. They are much broken and folded, but they are not crystalline. They are usually dark colored, showing both slaty cleavage due to pressure and a slatiness due to sedimentary structure. They are sometimes gritty with abundant quartz, but rarely become graywackes.

Overlying the Animikie is a coarse quartz-pebbly conglomerate, seen in the valley of the St. Louis near the east county line. This is followed by red sandstones and shales. The conglomerate is, at other places, followed by a great thickness of quartzyte, and together these represent the true Potsdam of New York. In Carlton county the quartzyte was never deposited, or was subsequently removed, and a later sandstone, represented by the Fond du Lac sandstone, comes directly and apparently conformably upon the conglomerate. But between the date of the conglomerate and these sandstones there was more or less igneous eruption in the immediate vicinity, and great lava sheets were spread over much of the country further east. Some of this igneous action was also cotemporary with these sandstones, judging


ST. LOUIS COUNTY
AITKIN COUNTY
PINE COUNTY
STATE OF WIS.
FOND DU LAC INDIAN RESERVATION
THOMPSON
KNIFE FALLS
MUSKEG
MOOSE LAKE
MAHTOWA
TWIN LAKES
NORTHERN PACIFIC R.R.
ST. PAUL AND DULUTH R.R.
CROMWELL
WRIGHT
CORONA
SAWYER
PINE GROVE
CLOQUET
KOMOKA
CARLTON
THOMSON
SUMMIT
OTTER CR.
WRENSHALL
BARNUM
MAHTOWA
PICKERING
Ancient Channel
Fifth Correction Line
Big Lake
Sandy Point
Perch Lake
Rocky Lake
Chub Lake
Hay Lake
Island L.
Eagle L.
Tamarac L.
Dead Fish L.
White Fish Lake
Old Outlet
Dam
Moose Horn R.
Dead Moose River
Otter Brook
Split Rock R.
Kettle River
Nemadji
Black Hoof Cr.
St. Louis River
Midway R.
T.49N.
T.48N.
T.47N.
T.46N.
R. XXI W.
R.XX W.
R XIX W.
R. XVIII W.
R. XVII W.
R. XVI W.
Explanation
Glacial
Till, flat or undulating
Till, rolling morainic
Till, locally covered by lacustrine clay or by sand
Cambrian
Hinckley sandstone
Taconic
Keweenawan (Trap?)
Slates and graywackes (Animikie?)
Keewatin
Slates and schists
Beach of Lake Nemadji
Roads
Trails
Railroads
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
CARLTON COUNTY
BY N.H. WINCHELL,

from the igneous materials which they contain. To these sandstones, therefore, the name Potsdam is also extended. They are of the date of the waning stages of the Keweenawan.

During this eruptive epoch there was a gradual subsidence of the region. The trap beds, more or less broken, the quartzyte and conglomerate of the Potsdam, the Animikie, and even some of the Archean, went successively below the ocean's waters. This event brought the later (Hinckley) sandstone nonconformable on these older formations, but where the Keweenawan traps did not disturb the orderly sequence, the Fond du Lac sandstones are presumably followed conformably by the later sandstone strata. The term Lower Cambrian includes the Animikie. The Middle Cambrian is represented, as supposed, by the Potsdam conglomerate and quartzyte, and the Upper Cambrian includes the sandstones that accumulated after the cessation of igneous disturbance, *i. e.*, the Hinckley and St. Croix sandstones and the associated limestones and shales to the commencement of the Lower Silurian.

There are three glacial lakes represented in Carlton county, formed, like lake Agassiz, by the waters resulting from the melting of the glaciers being dammed in by the contour of the country, while the lower outlet was closed by the glacier. One of these lakes was small, and was confined to Carlton county. It has been named lake St. Louis, and its outlet, 523 feet above lake Superior, was through Otter Creek and Mahtowa townships, uniting near Barnum with the Moose river valley, which is tributary to the Kettle river and the Mississippi. The second glacial lake had an outlet further south. This lake covered the Nemadji valley, and its outlet was through T. 46-18, at a hight of 468 feet above lake Superior. The old channel is very marked, but now nearly dry. The third glacial lake had its outlet by way of the Brulé-St. Croix valleys in Wisconsin. It appears to have been at least ten feet lower than the outlet of lake Nemadji. N. H. W.

PLATE LVII.

AITKIN COUNTY, 1899. WARREN UPHAM.

There are but three outcrops of the bedrock in Aitkin county. There is a quartzyte at the west side of Dam lake, in Kimberly, and a "diabase" about three miles toward the southwest, at one-fourth mile west from the south end of Long lake. There is granite in full force on the Snake river near the south line of this county, but in Kanabec, and at points between Snake river and Cowan's brook in Aitkin county, it is near the surface, as indicated by numerous blocks of a fine-grained, gray granite, seen in the glacial drift. The quartzyte has a length of outcrop of about 250 feet along the shore, and varies in width from fifteen to fifty or sixty feet, rising to a hight of four or five feet above the lake. It is so broken into blocks that no compact ledge is seen. The rock is a coarse quartz sandrock, or quartzyte, some of the grains having a lavender color, and there is but little doubt that it belongs to the same formation as the quartzyte at Pokegama falls, which is associated with the hematite ore of the Mesabi range. (See, however, the Pokegama Lake plate.)

The "diabase" is three miles southwest from the quartzyte and occurs on both sides of Long lake. It is really a very dark-colored, hornblendic gneiss, with biotite and a white and rarely pinkish feldspar resembling orthoclase. This rock presents the aspect of much of recrystallized Keewatin (or Coutchiching), and is quite certainly a part of the Archean and underlies the above quartzyte nonconformably.

The drift of Aitkin county would average probably between 100 and 150 feet in thickness. It is evidently from the north and northeast, but there is reason to believe that a considerable Cretaceous element, sometimes in the form of lignite, was also mingled with the drift. The till is prevailingly dark and somewhat bluish gray, except in the southeastern part of the county, where it has a reddish tint.

Morainic tracts are found in the northern part of the county and also in the southwestern, representing the Fergus Falls and the Leaf Hills moraines, as interpreted by Mr. Upham, but a larger part of the county is covered with a smoothly undulating or flat till sheet. Through the central portion, however, is a belt of sand and gravel, extending north and south, and along the Mississippi, the Willow and other valleys is a thick deposit of fertile post-glacial alluvium.

A small glacial lake, named lake Aitkin by Mr. Upham, covered much of the township of Aitkin. It probably extended also across the Mississippi northwestwardly, including much of the valley of Willow river. It was probably due to the long-continued existence of a glacial lobe in the basin of lake Superior, which was

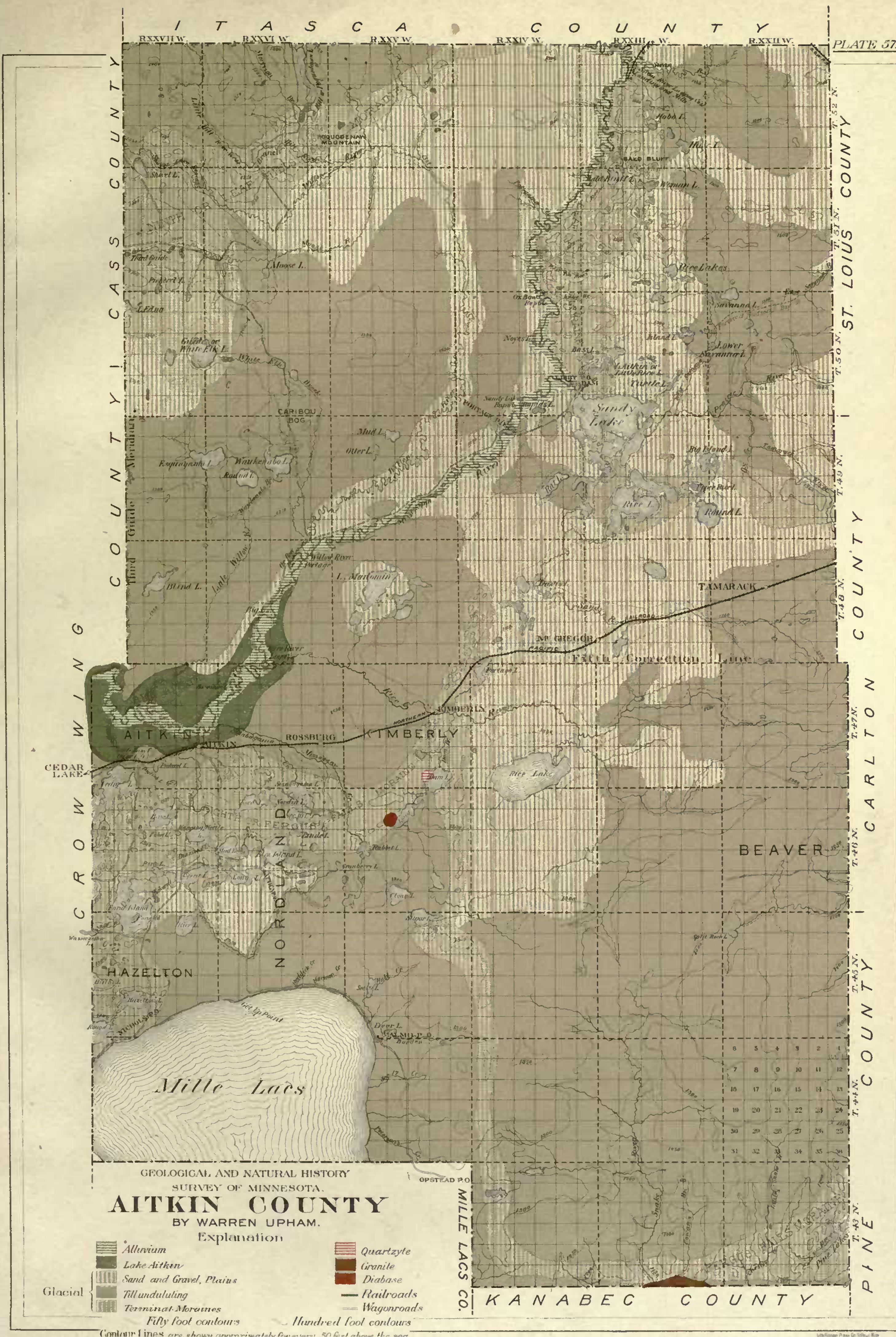


PLATE 57.
ITASCA COUNTY
CASS COUNTY
ST. LOUIS COUNTY
CROW WING
CARLTON COUNTY
PINE
KANABEC COUNTY
MILLE LACS CO.
R.XXVII.W.
R.XXVI.W.
R.XXV.W.
R.XXIV.W.
R.XXIII.W.
R.XXII.W.
T.52 N.
T.51 N.
T.50 N.
T.49 N.
T.48 N.
T.47 N.
T.46 N.
T.45 N.
T.44 N.
T.43 N.
POQUODENAW MOUNTAIN
BALD BLUFF
Hobb L.
Moose L.
Third Guide
L. Edna
Mud L.
Otter L.
CARIBOU BOG
Waukenabo L.
Sandy Lake
Rice Lakes
Savanna L.
Lower Savanna L.
Big Island L.
Round L.
Rice L.
Blind L.
L. Minnewawa
Third Guide Meridian
TAMARACK
McGREGOR
Fifth Correction Line
AITKIN
CEDAR LAKE
ROSSBURG
KIMBERLY
Rice Lake
Dam L.
Rabbit L.
Clear L.
Spirit L.
NORDLAND
BEAVER
HAZELTON
Split Rock L.
Deer L.
Mille Lacs
OPSTEAD P.O.
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
AITKIN COUNTY
BY WARREN UPHAM.
Explanation
Alluvium
Lake Aitkin
Glacial
Sand and Gravel, Plains
Till undulating
Terminal Moraines
Quartzyte
Granite
Diabase
Railroads
Wagonroads
Fifty foot contours
Hundred foot contours

thrust across the Mississippi valley further south, causing the flooding of much of the region of the Upper Mississippi in Aitkin and Cass counties. This was probably later than the existence of lake Agassiz.

The level of the water of Mille Lacs was formerly about fifteen feet higher than at present, as evinced by distinct beach ridges at that hight, seen on the north side of the lake. This may have been due to a glacial expansion from the same ice-lobe, shutting off the Rum river outlet at about the same time that lake Aitkin was formed by the obstruction of the Mississippi; or, as suggested by Mr. Upham, this beach ridge may be found to be submerged, or merged into the present beach by greater differential elevation toward the north, should it be traced carefully toward the south. If it was a glacial lake there may be found, perhaps, an outlet westward into the Mississippi river through the Nokasippi valley. N. H. W.

PLATE LVIII.

Cass County and Part of Crow Wing, 1899. Warren Upham.

Only two outcrops of rock are known in this area. One is near the Todd county line and the other is on Boy river, near the north side of T. 142–27. The rock of the former is gray granite, rather fine grained, containing both white and flesh-colored feldspar, and much epidote. Mica is scarce. In general this rock strongly resembles that seen in Ward township, Todd county, and in Ashley, Stearns county, and belongs to the Archean. It is crossed by two dikes of diabase, one being fifty to sixty feet wide and the other thirty feet. One bears S. 50° E. and the other S. 70° E., the latter being also the direction of a conspicuous system of joints.

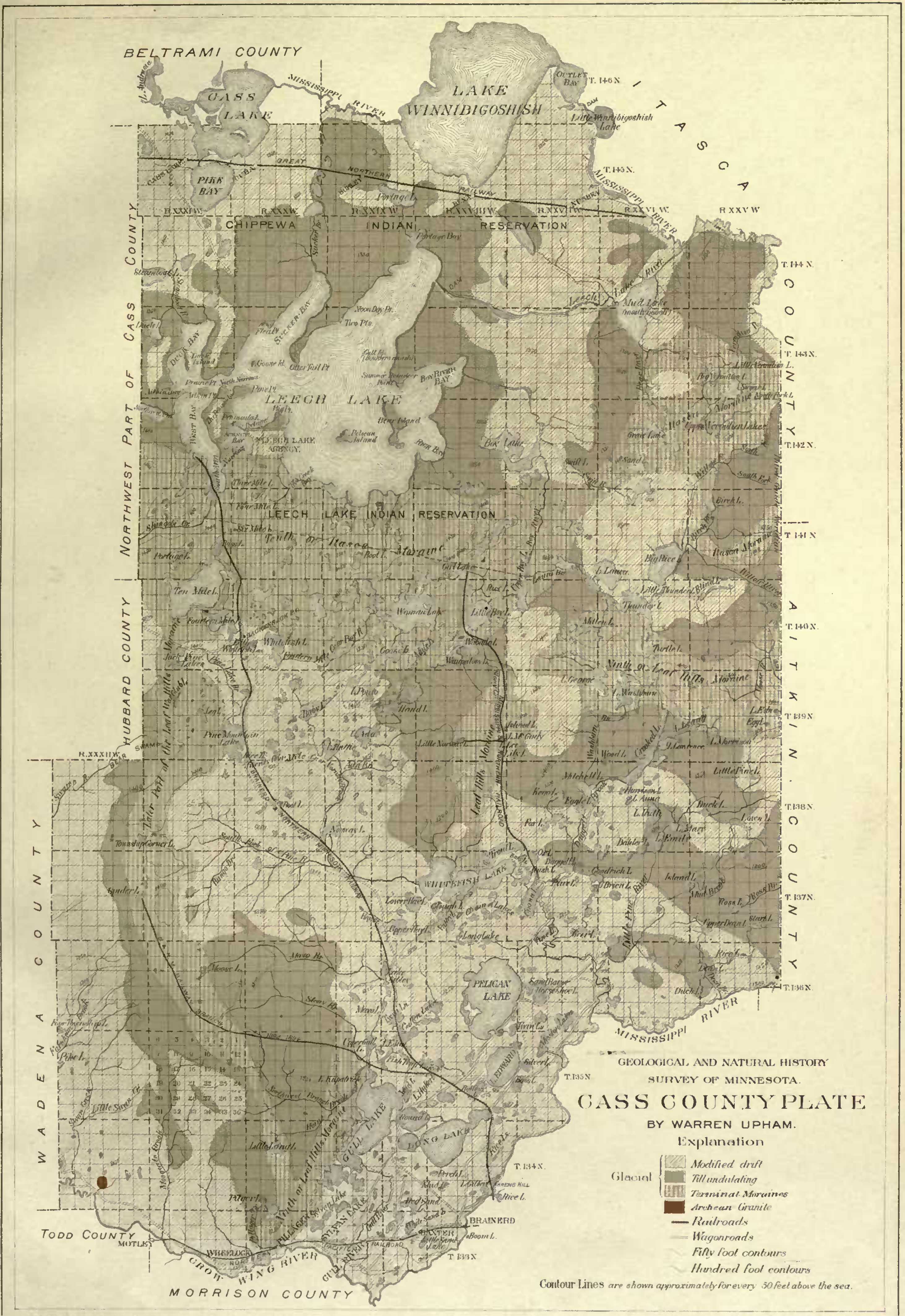
The other outcrop has not been seen by any officer of the geological survey, and its characters are unknown.

Cretaceous debris is found in the drift, including lignite, about the shores of lakes Leech and Winnibigoshish, but in the general absence of Winnipeg limestone pieces such Cretaceous cannot be referred for source to points toward the northwest. It is to be inferred that this debris came from Cretaceous underlying the drift in this county, or near adjacent to the north.

Two belts of terminal moraine pass through Cass county, one lying south of Leech lake, running in an east and west direction, and the other northeastwardly from Wheelock to the Aitkin county line. Mr. Upham considers the former as a continuation of the tenth or Itasca moraine, and the latter as a part of the ninth or Leaf Hills moraine.

There are some extensive plains of modified drift in Cass county, yet sometimes these are broken by extreme undulations that vary from twenty to forty feet between the hills and the valleys. Such drift is scattered to the southward from the morainic belts. The later moraine sent such water-borne gravel and sand widely over the central part of the county, and appears to have almost obliterated the characteristic features of the next earlier moraine through an interval north of Gull lake. In these gravel plains, as in others in counties further west, are isolated deep depressions in which sometimes lakes exist. These isolated depressions, or kettle holes, are attributable to isolated masses of the glacier which lay in the way of the gravel-bearing waters, and remained until the waters subsided. On melting, these isolated ice masses left vacancies in the gravel plain which have not been filled.

Long gravel ridges are found at various places. These are kames. They were formed by streams that flowed between ice walls, sometimes for several miles, washing the drift that fell from the ice on either side and carrying away the clay con-


BELTRAMI COUNTY
CASS LAKE
LAKE WINNIBIGOSHISH
MISSISSIPPI RIVER
ITASCA COUNTY
AITKIN COUNTY
WADENA COUNTY
HUBBARD COUNTY
Northwest Part of Cass County
TODD COUNTY
MORRISON COUNTY
CROW WING RIVER
PIKE BAY
GREAT NORTHERN RAILWAY
CHIPPEWA INDIAN RESERVATION
LEECH LAKE
LEECH LAKE AGENCY
LEECH LAKE INDIAN RESERVATION
WHITEFISH LAKE
PELICAN LAKE
GULL LAKE
LONG LAKE
BRAINERD
MOTLEY
T. 146 N.
T. 145 N.
T. 144 N.
T. 143 N.
T. 142 N.
T. 141 N.
T. 140 N.
T. 139 N.
T. 138 N.
T. 137 N.
T. 136 N.
T. 135 N.
T. 134 N.
T. 133 N.
R. XXV W.
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
CASS COUNTY PLATE
BY WARREN UPHAM.
Explanation
Glacial
Modified drift
Till undulating
Terminal Moraines
Archean Granite
Railroads
Wagonroads
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.

tained in it, retaining the coarser portion which the current was not powerful enough to transport. On the melting of the glacier the gravel ridge shows where the stream was located during the prevalence of the ice, and the swampy tract along either side shows the thinner drift sheet from which the clay was carried away and the gravel was concentrated to form the ridge. These long ridges graduated, near the ice border, into knobs and broken hills of little or no regularity of form or direction. This happened where the water from the glacier border was not collected into streams of considerable size but flowed down from the ice all along more evenly. Where there was not sufficient water to wash the drift the modified till was deposited.

N. H. W.

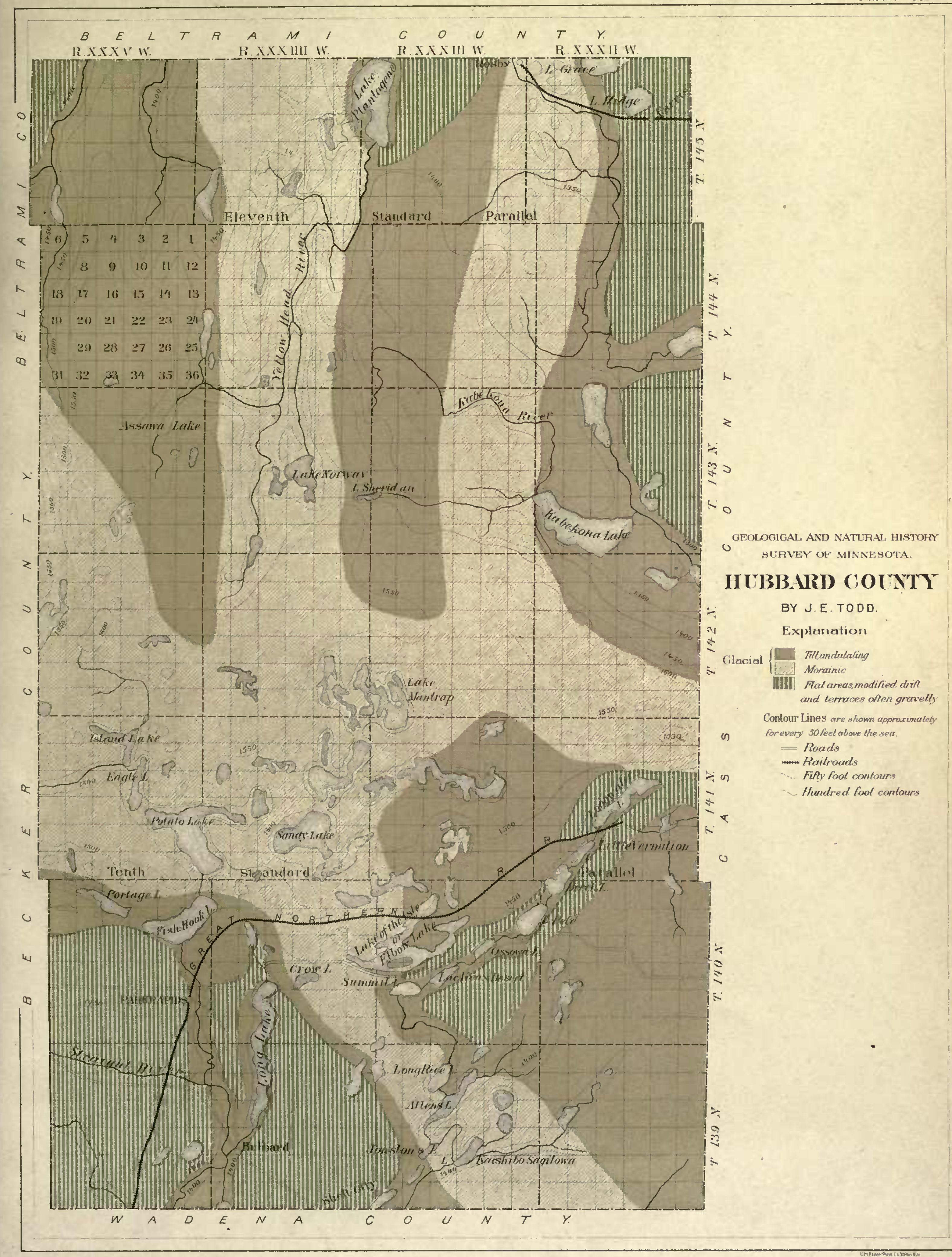
PLATE LIX.

HUBBARD COUNTY AND NORTHWESTERN PORTION OF CASS, 1899. J. E. TODD.

This area has no exposures of the bedrock, so far as known. A morainic belt crosses it from east to west, connecting toward the east with the moraine that lies south of Leech lake, called Itasca moraine by Mr. Upham. Another belt of morainic land runs apparently across the last in a north and south direction, and because of its association with the Schoolcraft (or Yellow Head) river in the north has been named by Mr. Todd the Schoolcraft River moraine. This passes east of Park Rapids and west of the head of Schoolcraft river, leaving the county in the vicinity of lakes Alice and Hattie, turning east and passing between lakes Bemidji and Turtle north of the bend of the Mississippi. A third moraine, called Cass Lake moraine by Mr. Todd, passes by the west end of lake Kabekona northward, turns east, and is crossed by the Mississippi at the Metoswa rapids, extending thence east and northeast. Mr. Todd suggests that the Itasca moraine, at Itasca lake, is of the nature of an interlobate moraine, with its apex eastward.

The till is uniformly of a gray color and constitutes the principal body of the glacial drift of the region. It is nearly free from limestone pieces. It hence seems not to have been derived in general from the northwest. About Fish Hook lake, however, in the southwest part of Hubbard county, limestone pieces are common. These are not like the hard and tough limestone seen along the Minnesota valley, but soft and impure, of a yellowish color, and may have been derived from some of the Lower Magnesian strata of the Upper Cambrian which possibly underlies the region. This is a distinction made by Prof. Todd.

Prof. Todd's hypothesis of the relations of the glacial moraines is one that seems to be in harmony with numerous facts, discovered in the northeastern part of the state since the correlation of the drift features proposed by Mr. Upham was published, going to show that a lobe of the continental ice-sheet was prolonged in time and in force after the ice had retreated from the western part of the state, and probably after the northwestern part of the state was freed from ice; and that hence some of the moraines that have been traced out in a general way about the western confines of the Lake Superior basin are due to that lobe rather than to the main continental glacier. The curving of the moraines northeastwardly from the region of Itasca lake, as represented by Prof. Todd, may be due to the existence of the Lake Superior ice-lobe over the region of the upper Mississippi. On the partial withdrawal southeastwardly of the northwestern border of that lobe, such lobe was probably still projected over the Mississippi valley as far north as to Pokegama falls,


BELTRAMI COUNTY.
R. XXXV W.
R. XXXIIII W.
R. XXXIII W.
R. XXXII W.
BELTRAMI CO.
BECKER COUNTY.
WADENA COUNTY.
CASS COUNTY.
T. 145 N.
T. 144 N.
T. 143 N.
T. 142 N.
T. 141 N.
T. 140 N.
T. 139 N.
Eleventh Standard Parallel
Tenth Standard Parallel
Lake Plantagenet
L. Grace
L. Hodge
Yellow Head River
Kabekona River
Assawa Lake
Lake Norway
L. Sheridan
Kabekona Lake
Lake Mantrap
Island Lake
Eagle L.
Potato Lake
Sandy Lake
Portage L.
Fish Hook L.
Great Northern R. R.
Lake of the Isle or Elbow Lake
Crow L.
Summit L.
Ossowa L.
Little Vermilion
Park Rapids
Straight River
Long Lake
Long Rice L.
Allens L.
Hubbard
Jonston's L.
Kwashibo Sagitowa
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
HUBBARD COUNTY
BY J. E. TODD.
Explanation
Glacial
Till, undulating
Morainic
Flat areas, modified drift and terraces often gravelly
Contour Lines are shown approximately for every 50 feet above the sea.
Roads
Railroads
Fifty foot contours
Hundred foot contours

causing a glacial lake to cover the areas of Leech, Cass and other lakes, having its outlet through Hubbard county by way of the remarkable chain of lakes leading southwestward to the headwaters of the Crow river. The course of this glacial channel has not been followed entirely to Leech lake, but it probably could be. N. H. W.

PLATE LX.

BECKER COUNTY, 1888. WARREN UPHAM.

This county is also so covered by drift that no rock outcrop has been discovered within its limits. There is reason for believing that a limestone formation underlies the central, elevated, part of the county. This belief is based on the topography, which shows a marked, rather abrupt uniform tableland or terrace rising from the flat, till-covered portion of the northwestern part of the county, to the altitude of 150 or 250 feet above the plains. This elevation crosses Lake Park, Audubon, Detroit, Richwood and White Earth and extends northward in Norman county. To the south it enters Clay county from the east, and passes through Eglund, Parke and Tansem, and through the entire extent of the most western range of townships in Otter Tail county. Throughout most of this distance this elevation is surmounted by a morainic belt, as shown by the maps of volumes I and II. This terrace-like ascent from the Red River valley is a remarkable and conspicuous feature for more than 100 miles. It rises toward the north from the average altitude, in Otter Tail county, of 1,400 feet, to 1,600 feet in White Earth, in Becker county. Owing to the occurrence of numerous fragments of magnesian limestone on the brow of this terrace, sometimes ten or twelve feet in length, west from the White Earth Agency, and at one or two miles south of Audubon, Mr. Upham has suggested that probably an escarpment of such limestone is the primary cause of this terrace. In that case this magnesian limestone, which is probably the Upper Cambrian, may extend for many miles toward the east and north, underlying the region of the sources of the Mississippi and of the Red River of the North, and extending with a northwestward dip past the southwestern shores of Lake of the Woods.

The northwestern part of the county contains a till which was derived largely from the Cretaceous, and such drift was probably brought from the northwest. The rest of the county contains a drift which was derived more from the north, and perhaps from the east by the action of the Lake Superior ice-lobe.

The name White Earth may have been derived from a shell marl bed found in the banks of the Buffalo river in sec. 28, T. 141–41.

About five-sixths of the limestone boulders of this county make a white lime, the rest a yellowish lime. This indicates the Upper Silurian as well as Cambrian limestones as the source of these fragments. N. H. W.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

BECKER COUNTY

BY WARREN UPHAM.

Explanation.

Modified Drift { Flat or undulating; Rolling or kame-like.

Till { Undulating or rolling; More prominently rolling, morainic; Knolly and hilly; Terminal Moraines.

Contour Lines are shown approximately for each 50 feet above the sea.

PLATE LXI.

CLAY COUNTY, 1888. WARREN UPHAM.

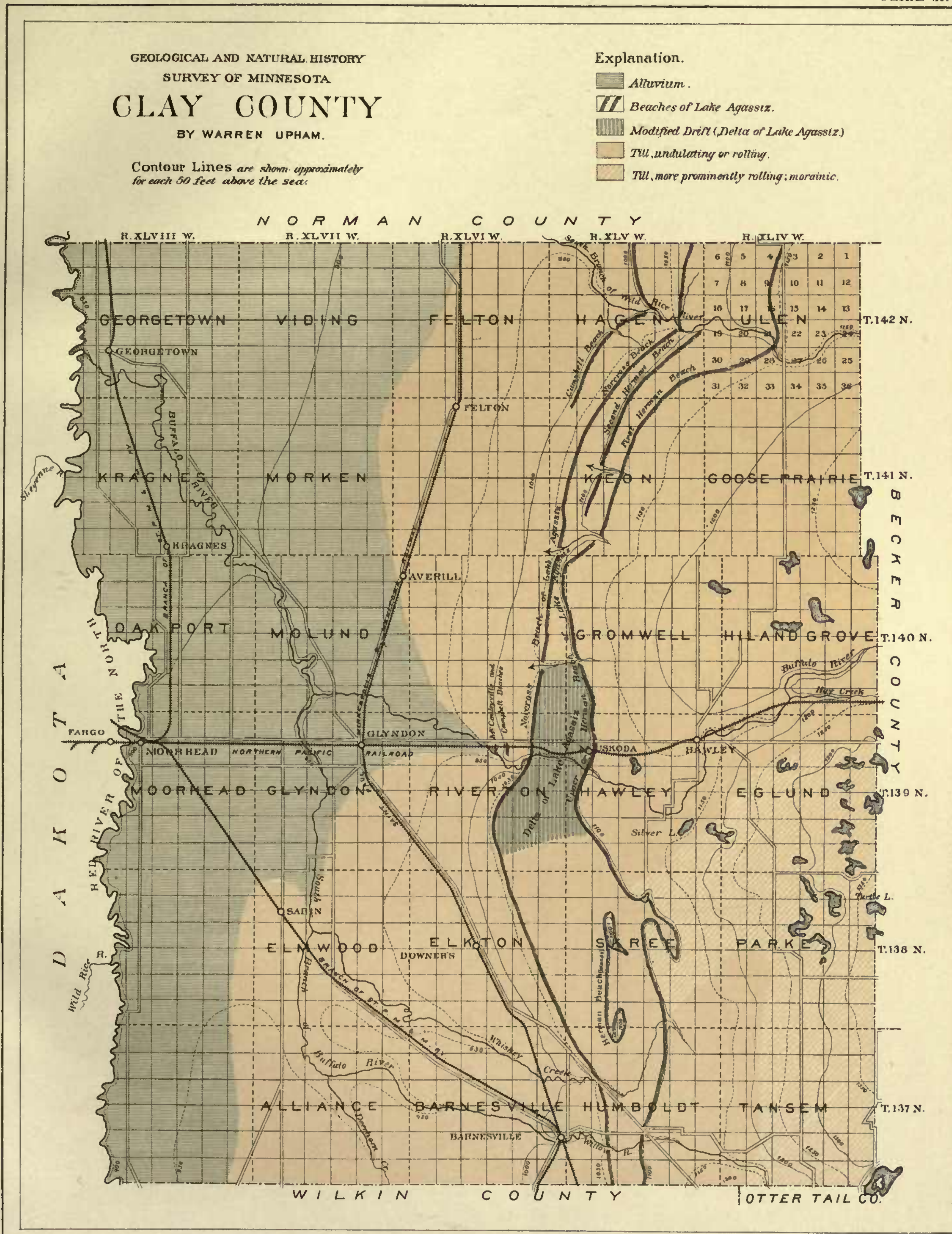
About two-thirds of the area of this county were covered by lake Agassiz, the beach lines of which are very marked. East of the highest, or Herman, beach the general surface at first falls away for a distance of say a quarter of a mile, but rises then into a distinct rolling or undulating plateau of drift consisting essentially of till. West of this beach, and more especially west of all the beaches, the surface is almost flat, presenting an oceanic expanse over which distant objects rise first in mirage, and later as ships at sea, with only their tops visible. This flatness continues to and beyond the Red River of the North, which meanders in a very crooked course northward in a narrow, shallow channel which it has excavated in the drift surface. West of the beaches are no lakes, but east of them are numerous lakes like those of the morainic regions of Becker county. Toward the north the Herman beach becomes double, and still further north the other beaches are also doubled or tripled.

In crossing this plain from the west to the east, two terrace-like elevations are noticeable. One occurs at six miles east of Glyndon, running about north and south. Here the ascent is about 200 feet in the distance of two or three miles. The other terrace is that mentioned in connection with the Becker County plate (Plate LX), and is especially distinct at White Earth Agency, about twelve miles east of the east line of Clay county, rising about 300 feet still higher. These gigantic terraces are supposed to be due to rock escarpments, now buried under the drift sheet, formed by preglacial erosion. The western scarp is probably caused by a westward facing Cretaceous bluff, and the eastern, or highest, by a westward facing bluff of Paleozoic limestone. The western (Cretaceous) bluff was probably much reduced and rounded over by the operations of the glacial epoch; but the hight of the Paleozoic escarpment was probably not so much diminished, and at the last one of the moraines of the region was piled upon it through much of its course, giving it an apparent increase of hight.

An interglacial forest bed has been found in the region of Barnesville, overlain by twelve feet of till, the analogue of that found in Mitchell, Wilkin county.

Along the immediate Red River valley the surface consists of stratified clay which proves to be from sixty to ninety feet thick. This lies on the till and extends right and left for several miles, no stones being visible on the surface. This clay is supposed, by Mr. Upham, to be due to the river itself in its earlier history, when it flooded considerable areas, rather than to lake Agassiz. Eastward from this alluvium the till rises to the surface, and stones appear.

The till is also covered by sand and clay, apparently of the nature of delta deposits, at Muskoda, brought into lake Agassiz by the Buffalo river at the time of the



LITH. PIONEER PRESS CO. ST. PAUL.

Herman stage of that lake. This is about two miles wide and extends north and south about seven miles, limited on the west by the Norcross beach.

The county is essentially a monotonous prairie, which hardly will bear the statement applied to many other counties "with scattered trees along the water-courses."

The stratified clays furnish brick, and the boulders of limestone furnish excellent quicklime. Brickmaking is carried on extensively at Moorhead, and quicklime is burned at several places, particularly in Eglund and in Parke. N. H. W.

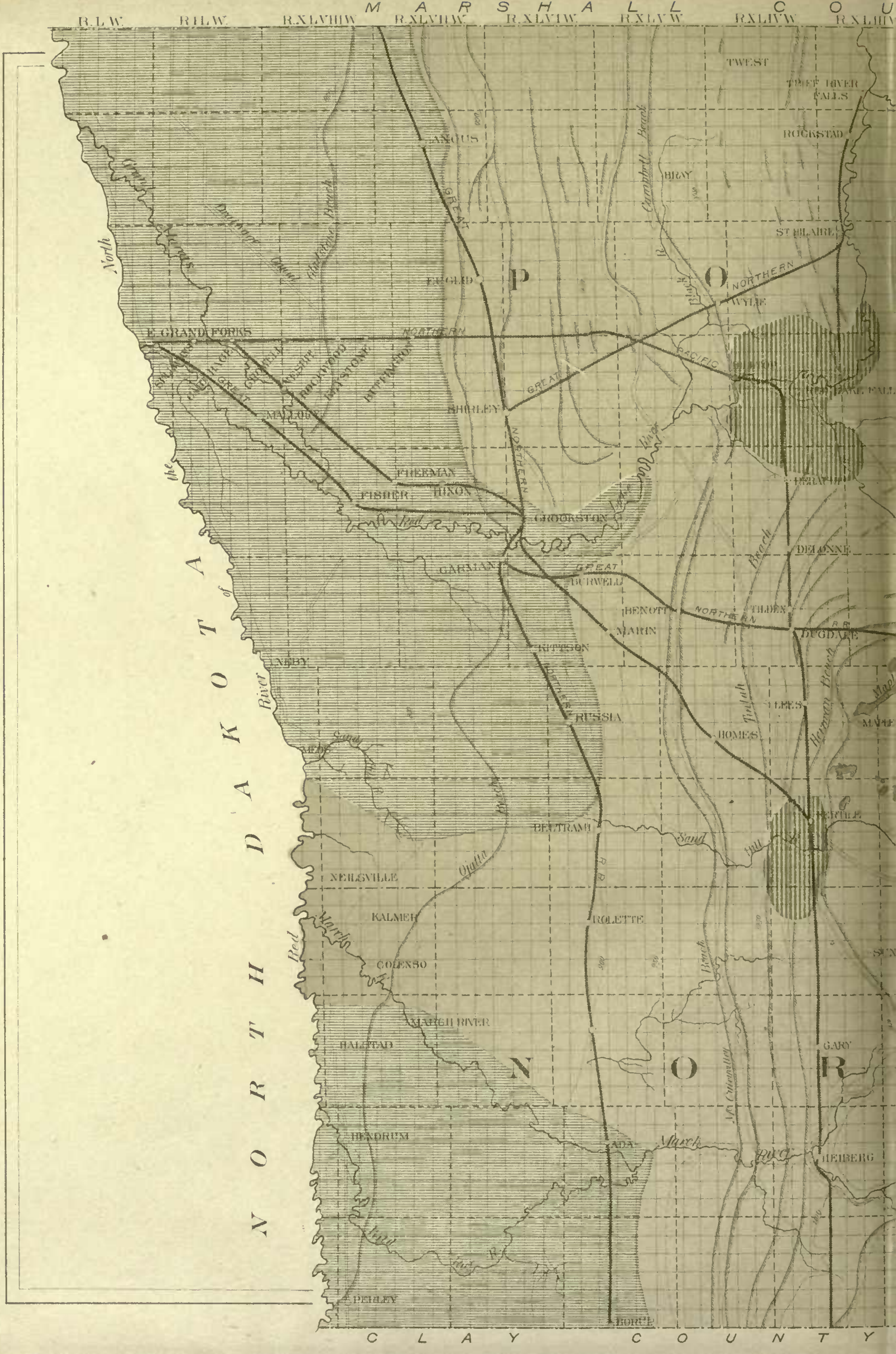
PLATE LXII.

Polk and Norman Counties, 1899. J. E. Todd.

Throughout the whole of this large area no outcrop of the bedrock is known, but the topography and drift features present interesting characters. While in general this region is covered by till, there are extensive tracts that are characterized by modified drift. The largest of these are along the Red River of the North. A fine laminated clay forms the soil over a belt that runs north and south, and is about eighteen miles wide. This clay is thinner toward the east, and apparently fades out gradually, allowing the till to form the soil. It extends further east up the valley of the Red Lake river than elsewhere, and also forms a large patch at Red Lake falls. This broad belt suffers an interruption, however, in northwestern Norman county, where the till rises to the surface continuously from the main till area to the Red river, forming a cross-belt about ten miles wide. This cross-belt of till is believed to be due to morainic accumulation submerged for a long time by lake Agassiz. Other patches of modified drift, due to the free action of water on the till in the act of deposition, as explained by Mr. Upham, are found in the eastern part of the county, one as a delta of Sand Hill river at the time of the formation of the Herman beach of lake Agassiz, and others as the result of local drainage from the glacier at the time of the accumulation of the morainic drift. The belt of modified drift which starts from the moraine in the north part of Lindsay, Polk county, running southwestwardly to the south part of Winger, in the same county, coinciding there with the valley of Sand Hill river, marks probably the course of a glacial stream along the border of the glacier when it filled the Red River valley and extended eastward to about that place. At a later date, as the ice withdrew beyond the Herman beach at this latitude, the same stream, as interpreted by Mr. Todd, united with lake Agassiz in the northwest quarter of the town of Lindsay, and was nearly cotemporary with the formation of the stony, narrow moraine, or kame, which is found in secs. 31, 32 and 33, T. 150-40.

Other ancient stream courses, probably having similar origin and slightly earlier date, are those indicated by the narrow belts of modified drift, running from the moraine, or across it, in the southeastern part of Norman county.

Mr. Todd suggests a somewhat different succession of events for the glacial history of these counties from that expressed by Mr. Upham, viz, he supposes the glacier lingered longer in the valley of the Red River of the North than on the highlands of the "park region," and hence that there was a large interlobate area between the Lake Superior ice-lobe and the Red River lobe, which was the scene of great



M A R S H A L L C O U
R.L.W.
R.XLVIII.W.
R.XLVII.W.
R.XLVI.W.
R.XLV.W.
R.XLIV.W.
TWEST
THIEF RIVER FALLS
ROCKSTAD
ANGUS
BRAY
Campbell Beach
ST HILAIRE
EUCLID
P
O
WYLIE
NORTHERN
E. GRAND FORKS
NORTHERN
PACIFIC
GREAT
SHIRLEY
MALLORY
GREAT
NORTHERN
FREEMAN
FISHER
HIXON
CROOKSTON
Red
GARMAN
GREAT
DURWELD
BENOIT
NORTHERN
TILDEN
DELONNE
MARIN
DUGDALE
KITTSON
NESBY
River
RUSSIA
LEES
HOMES
Beach
Herman Beach
BELTRAMI
Sand
NEILSVILLE
KALMER
Ojata Beach
ROLETTE
COLENSO
MARSH RIVER
HALSTEAD
N
O
R
GARY
ADA
Marsh
HEIBERG
HENDRUM
PERLEY
BORUP
NORTH DAKOTA
North
the
of
Red
C L A Y C O U N T Y

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

POLK AND NORMAN COUNTIES

BY J. E. TODD.

Explanation

Recent { Alluvium and lacustrine
Delta and other modified drift

Glacial { Till, flat or undulating
Morainic

Kames

Beaches

Railroads

Fifty foot contours

Hundred foot contours

Roads

Contour Lines *are shown approximately for every 50 feet above the sea.*

[Note. *Below the highest beach line the till is more or less covered by lacustrine deposits.*]

morainic confusion and increased accumulation, accompanied by powerful drainage which gave rise to glacial streams that must have taken their courses toward the south, through the moraines that had previously been accumulated.

This is not the proper place to present the reasons for this hypothesis, but to the writer it appears to be supported by facts which have been brought to light in the eastern part of the state, later than Mr. Upham's principal study, and by considerations that have been mentioned already in this atlas (Plates XLVII and XLVIII). It is apparent that, if this hypothesis be correct, it will affect materially the interpretation of the morainic belts, and their assignment to this or that of the great ice-lobes.

These counties, although containing much flat, swampy land, yet embrace much that is dry and suitable, without drainage, to farming, and possess a fertile, deep soil.

N. H. W.

PLATE LXIII.

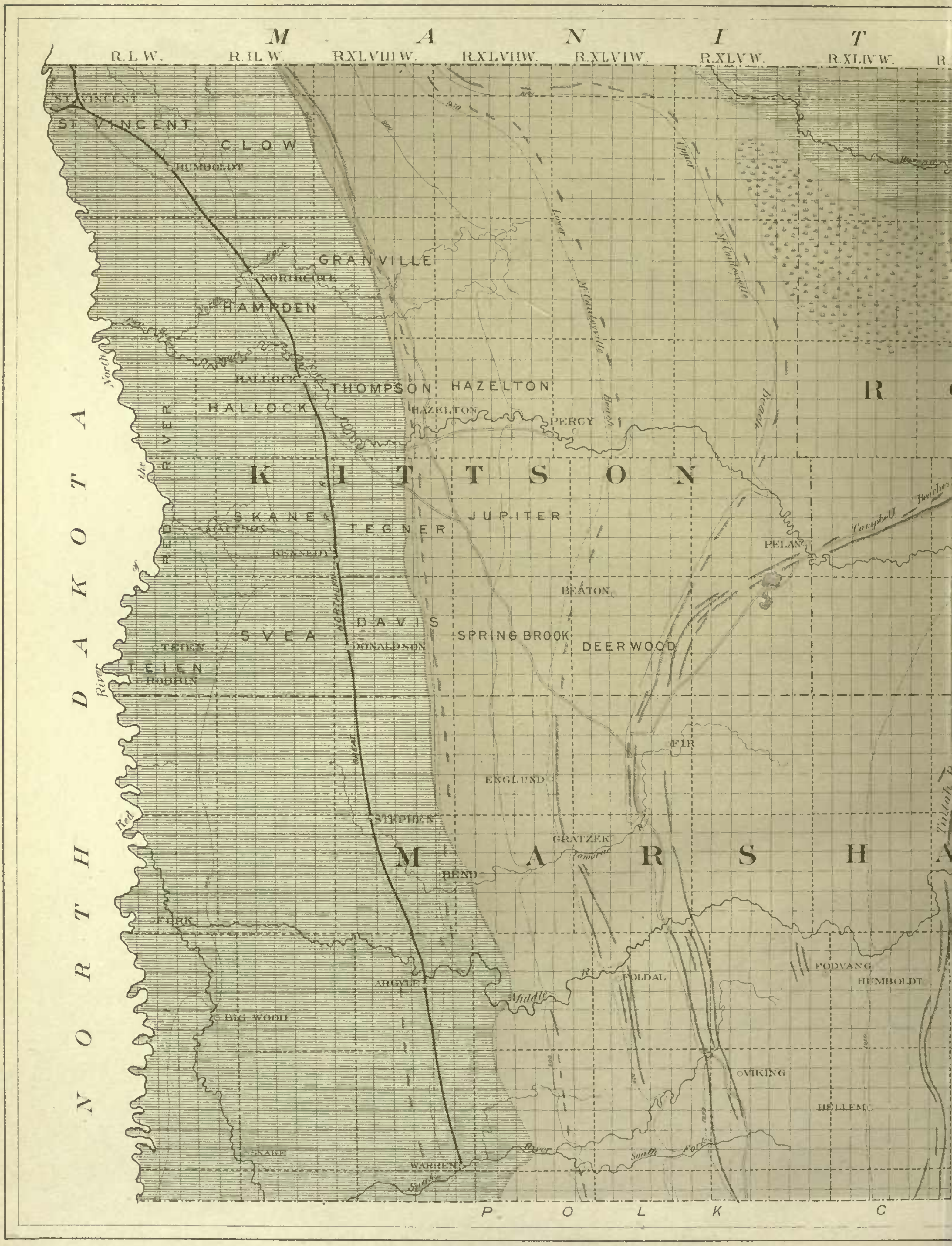
KITTSON, ROSEAU AND MARSHALL COUNTIES, 1899. J. E. TODD.

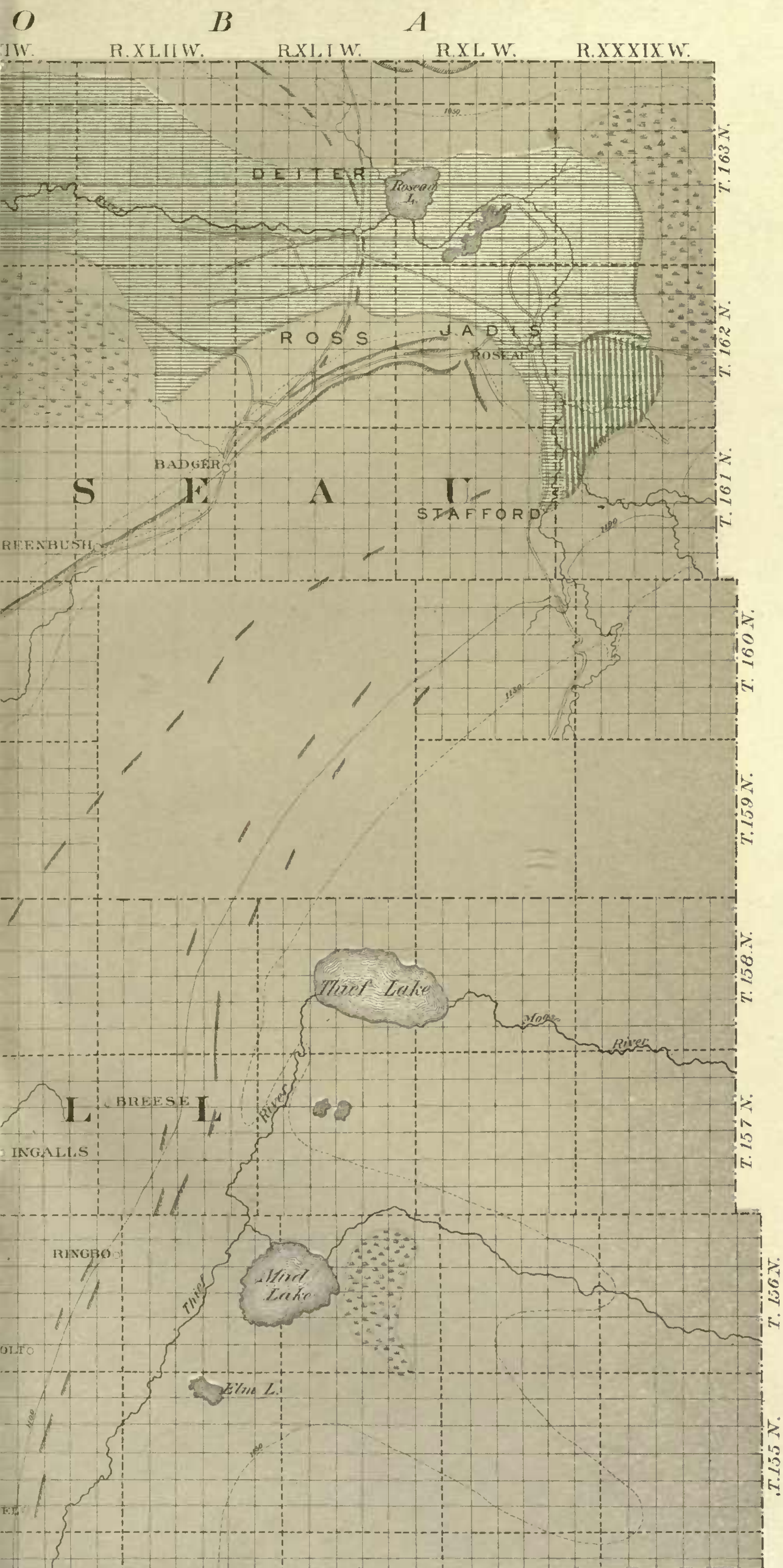
The area of these counties was embraced within the basin of lake Agassiz, and is flat and often swampy. It is crossed, fortunately for travel, by the gravelly beaches of that lake, but their actual location has not been determined in detail, except in a part of the area. A belt of lacustrine clay accompanies the Red River of the North, from fifteen to eighteen miles wide, and similar clay is found elsewhere, especially along the Roseau river, in Roseau county. There is higher and dryer land in southeastern Marshall county, and especially on the west side of Thief river, in that county, and also in the southeastern part of Roseau county. These tracts, connected with a larger tract further east, were probably a part of Beltrami island, which rose above the waters of lake Agassiz.

The streams have excavated but shallow channels in the clayey drift, and in no place have they uncovered the bedrock, so far as known, thus proving the comparative recentness of their birth. They sometimes lose themselves in superficial marshes, or muskegs, and spread over much of the country, reappearing again at the points of drainage from those marshes.

Mr. Todd thinks that the last point uncovered by the glacier was the northeastern part of Roseau, and the latest uncovered by the retreat of lake Agassiz was the northwestern part of Kittson county.

In the northwestern part of this area is much salt water. This permeates much of the surface water in the vicinity of saline springs. Such water is found, by sinking deep wells, not only in the gravelly beds in the drift, but also in the underlying rocks. A well at Humbolt penetrated to the depth of 644 feet. At 180 feet it entered a coarse magnesian limestone, the lithologic characters of which are like those of the Lower Magnesian of the Mississippi valley. This is 295 feet thick. Beneath this was a sandstone of rounded quartz grains, having a thickness of seventy-one feet. Then came shale, red, green, unctuous, gritless, resembling the red shale that has been penetrated at a number of places in the central part of the state, lying below the St. Croix sandstone, having a thickness here of ninety-two feet. The drill then entered mica schists of the Archean and the work ceased. Brine flowed constantly from this well after it reached the depth of 165 feet, in the drift, and increased in amount in the sandstone below the magnesian limestone. On analysis this brine was found to be superior to that used in Michigan for the manufacture of salt, and if fuel could be got cheap enough, or perhaps even by solar evaporation alone, it could be made a source of revenue to Kittson county. N. H. W.


M A N I T
R.L.W.
R.ILW.
R.XLVIII W.
R.XLVII W.
R.XLVI W.
R.XLV W.
R.XLIV W.
ST. VINCENT
ST. VINCENT
CLOW
HUMBOLDT
GRANVILLE
NORTHCOTE
HAMPDEN
HALLOCK
THOMPSON
HAZELTON
HALLOCK
HAZELTON
PERCY
R
K I T T S O N
SKANE
TEGNER
JUPITER
KENNEDY
PELAN
BEATON
DAVIS
SVEA
SPRING BROOK
DEERWOOD
DONALDSON
TEIEN
ROBBIN
FIR
ENGLUND
STEPHEN
GRATZEK
M A R S H A
BEND
FORK
FODVANG
FOLDAL
HUMBOLDT
ARGYLE
BIG WOOD
VIKING
HELLEM
SNAKE
WARREN
P O L K C
N O R T H D A K O T A
RED RIVER
Campbell Beaches
Red River
Middle River
South Fork
Lower St. Campbell Beach
Upper St. Campbell Beach
Tamarac



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

KITTSON, ROSEAU AND MARSHALL COUNTIES

BY J. E. TODD.

Explanation

Recent { Alluvium and lacustrine
Delta deposit
Glacial { Till, flat or undulating } more or less covered by lacustrine beds
Beaches
Roads
Railroads
Fifty foot contours
Hundred foot contours

Contour Lines *are shown approximately for every 50 feet above the sea.*

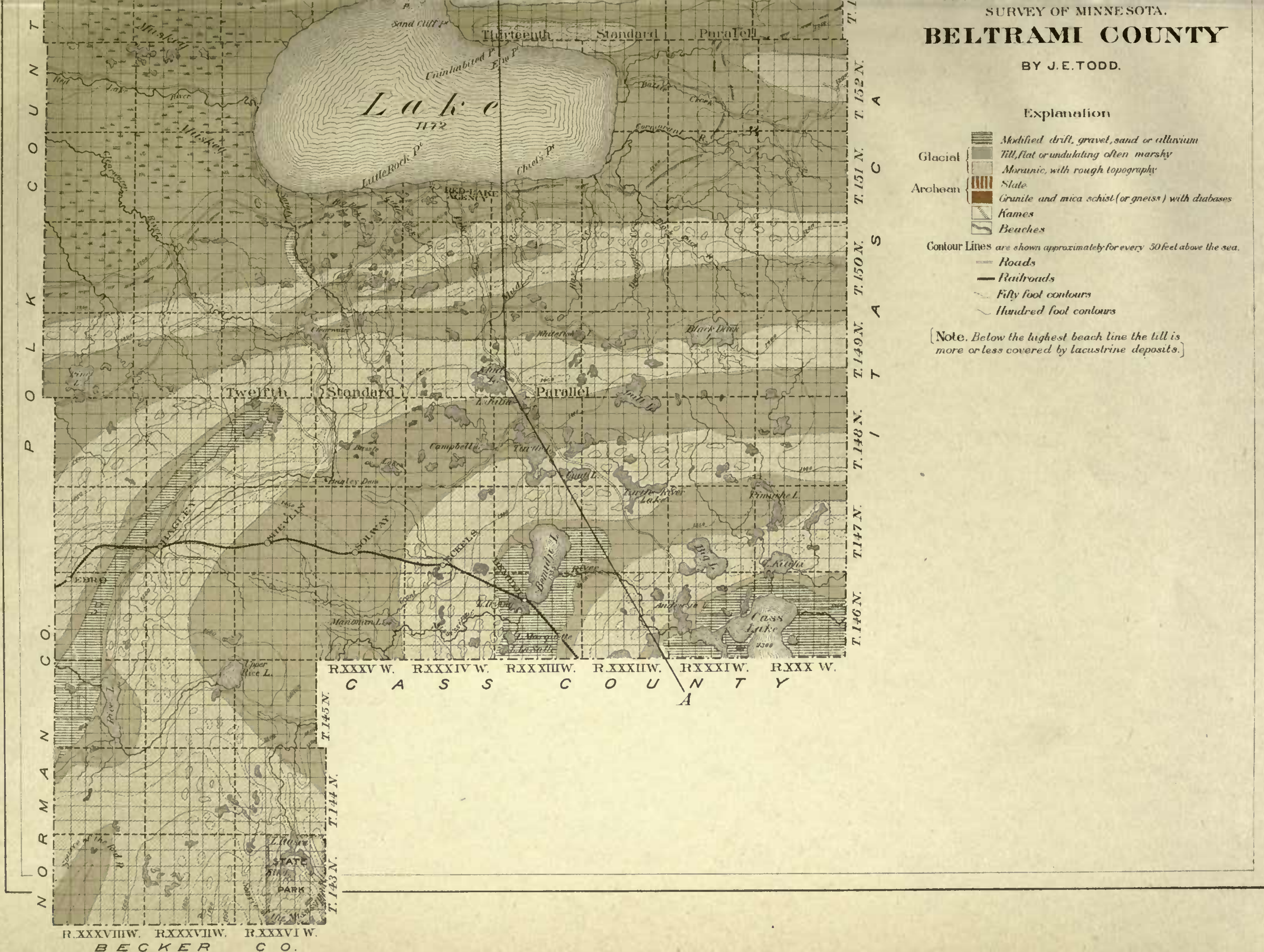
PLATE LXIV.

BELTRAMI COUNTY, 1899. J. E. TODD.

That portion of Beltrami county which was submerged by lake Agassiz (except Beltrami island) is separated from that which was not by a line running east and west approximately through town 150 north, but toward the east boundary of the county bearing northward so as to enter towns 151 and 152. The area of lake Agassiz has the well known physical features of the basin of the Red River of the North, excepting a small tract, not well known, which lies in the north central part of the county, which rose above the surface of that lake, increasing in size in the later portion of its history until it included probably fifteen to twenty townships, and was at last blended into the marshy tracts that still surround it, lying not much above the Lake of the Woods. That part of the county lying south of the above mentioned line is one of moraines and lakes, with all the diversity which marks the "park region" of Otter Tail and Becker counties.

The water divide between the waters flowing south to the Mississippi and those tributary to the Red River of the North is quite invisible. There is an intricate inosculation by means of many lakes and winding streams over an undulating, broad tract, so that it is with considerable difficulty that the actual divide can be followed. Some lakes, near the watershed, having no visible outlets, probably are drained both ways by entering the gravel beds of the drift. Lake Julia is described by Beltrami as one of that kind. He considered it the source of the "Bloody" river as well as of the Mississippi, but Mr. Todd says it lies, with other lakes, in the course of a broad depression or channel that crosses the main divide and which once, probably during the later part of the ice-period, was a water-way of drainage from the upper morainic regions of the Mississippi to the valleys tributary to Red lake.

According to the direction of the moraines in the southern part of the county, Mr. Todd has inferred that some of the southern ones were formed by an ice-lobe extending westward from the region of lake Superior, about the same time that the greater lobe of the Red River valley was on the northern part of the county, the two lobes having a reëntrant interlobate area about where Itasca lake lies. Into this interlobate area were accumulated not only larger amounts of morainic debris, but also a more copious discharge of water, the latter having its escape to the westward through a channel that crosses the moraine about a mile northwest from lake Itasca, and at a later date through a valley that extends southwestward from upper Rice lake and into Norman county, and at a still later date by the Clearwater valley. It is also apparent, according to Mr. Todd's descriptions and interpretations, that a


SURVEY OF MINNESOTA.
BELTRAMI COUNTY
BY J.E.TODD.
Explanation
Glacial
Modified drift, gravel, sand or alluvium
Till, flat or undulating often marshy
Morainic, with rough topography
Archean
Slate
Granite and mica schist (or gneiss) with diabases
Kames
Beaches
Contour Lines are shown approximately for every 50 feet above the sea.
Roads
Railroads
Fifty foot contours
Hundred foot contours
[Note. Below the highest beach line the till is more or less covered by lacustrine deposits.]
POLK COUNTY
NORMAN CO.
BECKER CO.
CASS COUNTY
ITASCA
Lake
1172
Little Rock Pt
Chiefs Pt
Sand Cliff Pt
RED LAKE AGENCY
Thirteenth Standard Parallel
Twelfth Standard Parallel
EBRO
BAGLEY
SHEVLIN
SOLWAY
NICKELS
BEMIDJI
Bemidji L.
Cass Lake
Upper Rice L.
Rice L.
Campbell L.
Turtle L.
Turtle River Lake
Black Duck
Pimushe L.
STATE PARK
L. Itasca
T. 143 N.
T. 144 N.
T. 145 N.
T. 146 N.
T. 147 N.
T. 148 N.
T. 149 N.
T. 150 N.
T. 151 N.
T. 152 N.
R. XXXVIII W.
R. XXXVII W.
R. XXXVI W.
R. XXXV W.
R. XXXIV W.
R. XXXIII W.
R. XXXII W.
R. XXXI W.
R. XXX W.
A


MARSHALL CO.
ROSEAU CO.
Fourteenth Standard
Fifteenth Standard Parallel
Parallel
Lake of the Woods
Red
Winter Road
Rapid River
Roseau R.
Boudette R.
Oak Point
Long Pt.
Stony Pt.
Rocky Pt.
Cormorant Rock
1060
B
T. 154 N.
T. 155 N.
T. 156 N.
T. 157 N.
T. 158 N.
T. 159 N.
T. 160 N.
C O U N T Y
Lake of the Woods
INTERNATIONAL BOUNDARY
Oak Point

similar flow of glacial waters passed from Turtle lake northward to Mud lake and the Mud River valley, reaching lake Agassiz. This history is plainly the commencement of that series of events which characterized the region of the upper Mississippi, marked by a fluctuating glacial lake caused by the Lake Superior ice-lobe, one of whose later outlets was by way of the remarkable chain of lakes described in connection with Hubbard county (Plate XXXIX). This is a very important and interesting part of the glacial history of the state which remains to be worked out by detailed field examination.

Archean (and perhaps Keweenawan) rocks are found on the islands and shores of Lake of the Woods, and Mr. Todd suggests that probably Cretaceous constitutes the nucleus of Beltrami island. N. H. W.

PLATE LXV.

ITASCA COUNTY, 1899. U. S. GRANT.

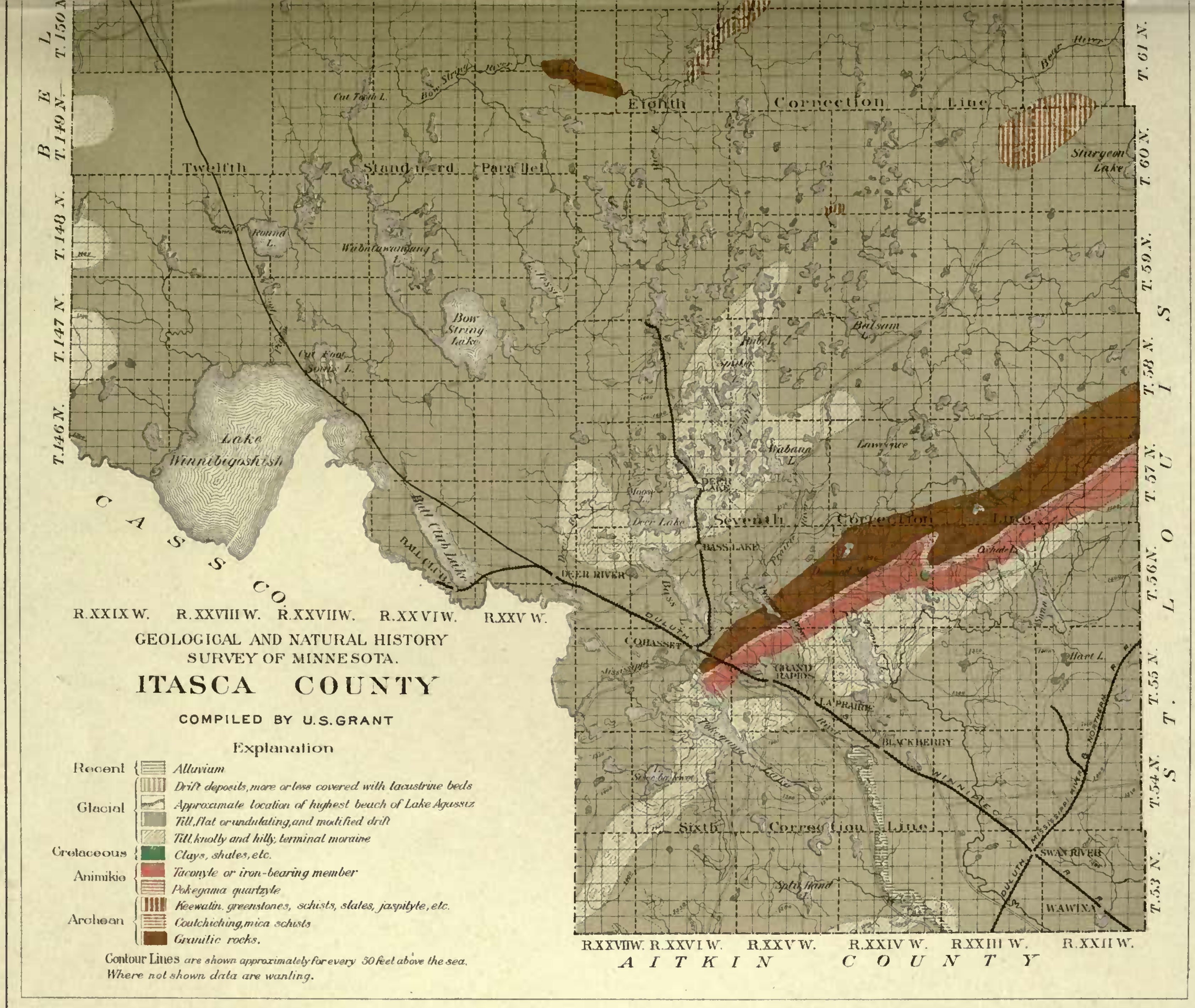
Granites, schists and greenstones, the last probably sometimes carrying ore like that of the Vermilion Iron range, belonging to the Archean, underlie the most of this county. Across the southeastern corner of the county the iron-bearing rocks of the Mesabi Iron range have occasional outcrops, lying on the granite. They have an outcropping belt about two miles wide, and so far as known consist of quartzyte and taconyte. Overlying these are supposed to be the black slates found in that position further east, belonging to the Animikie, but they have not been proven to occur in this county.

Unconformably upon the foregoing the Cretaceous is known to lie, having been found at various places on the Bowstring and Little Fork rivers, and also on the Mesabi Iron range.

The southern one-third part of this county is quite broken by morainic deposits, and sprinkled thickly with lakes. It is probable that when it is carefully examined certain continuous moraines can be traced entirely across the county, but at present it can only be said, from the observed directions of glacial striæ, and from what is known of Beltrami county, that the Lake Superior ice-lobe had a maximum northern limit along a line running from the centre of town 149 on the western boundary east-northeast to the south side of town 64 at the eastern side of the county. It is probable that in some of its earlier history this lobe was confluent about along this line with the more north-south ice-flow, which was a part of the great Laurentide glacier; but it appears to have maintained independent existence and movement in this county after the withdrawal of the main glacier entirely from this county. Yet, at a date not much later than the uncovering of northern Itasca county, the northern ice-lobe must have covered Lake of the Woods, in its northern part, Rainy lake and the region both east and west, thus obstructing the drainage to Hudson bay and forming that extension of lake Agassiz which included northern Beltrami and Itasca counties.

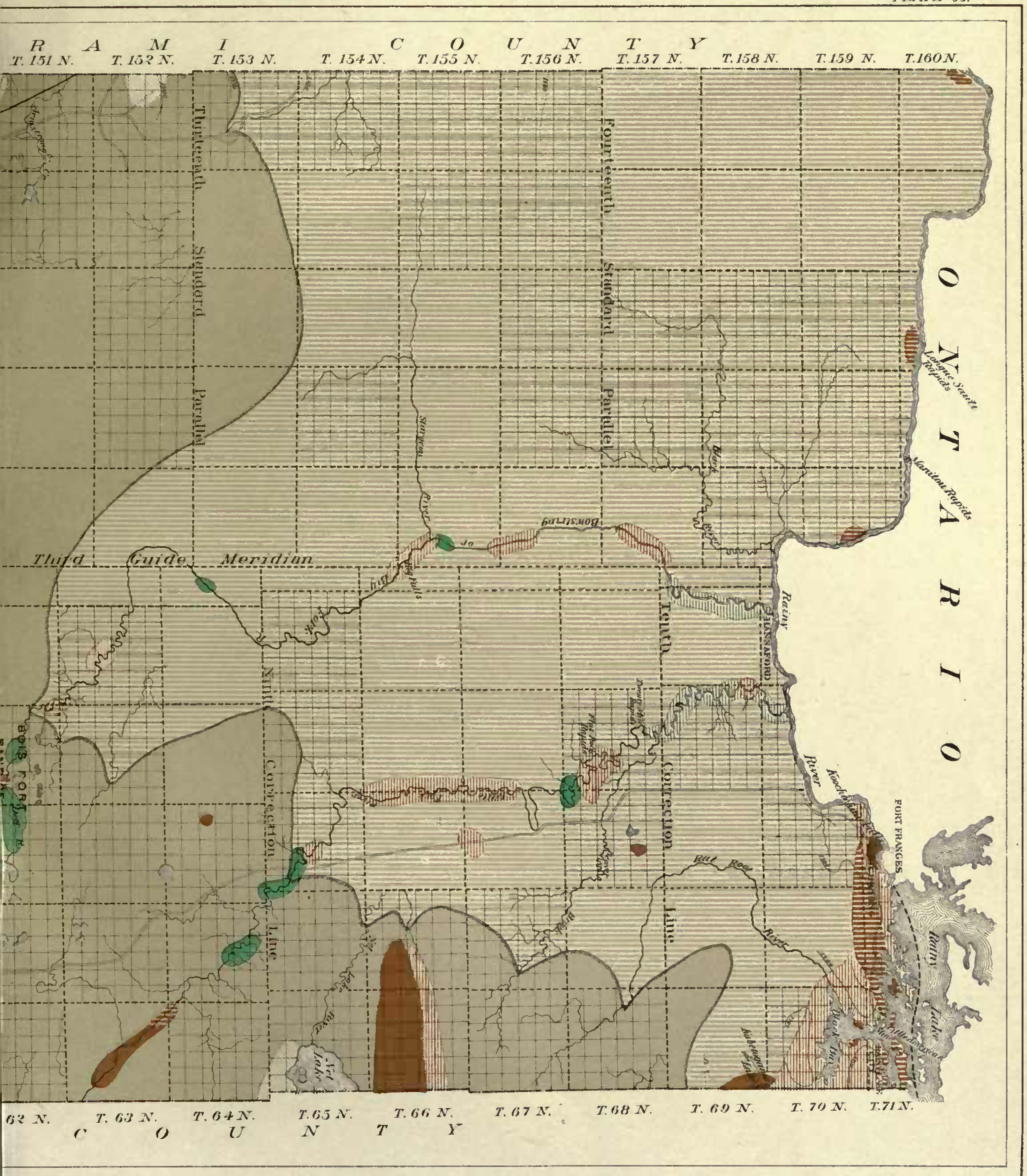
It is because of the prevalence of lake Agassiz that the northern portion of the county is smooth and nearly free from lakes, and that a thin-bedded, horizontal, fine clay, the result of its sedimentation, is found along the main streams.

The extreme northeastern part of Itasca county, bordering on Rainy lake, is quite different from all the foregoing, in that the drift deposits are quite scant, thus belonging, in glacial history, with the northern part of the Lake of the Woods, and with much of Minnesota further east. Here the schists and granite are abundantly exposed, indicating that the glacier margin retired rapidly toward the northeast. No



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
ITASCA COUNTY
COMPILED BY U.S.GRANT
Explanation
Recent
Alluvium
Glacial
Drift deposits, more or less covered with lacustrine beds
Approximate location of highest beach of Lake Agassiz
Till, flat or undulating, and modified drift
Till, knolly and hilly, terminal moraine
Cretaceous
Clays, shales, etc.
Animikie
Taconyte or iron-bearing member
Pokegama quartzyte
Archean
Keewatin, greenstones, schists, slates, jaspilyte, etc.
Coutchiching, mica schists
Granitic rocks.
Contour Lines are shown approximately for every 50 feet above the sea.
Where not shown data are wanting.
R.XXIX W.
R.XXVIII W.
R.XXVII W.
R.XXVI W.
R.XXV W.
R.XXVII W.
R.XXVI W.
R.XXV W.
R.XXIV W.
R.XXIII W.
R.XXII W.
AITKIN COUNTY
CASS CO.
BEL
ST. LOUIS
T.146 N.
T.147 N.
T.148 N.
T.149 N.
T.150 N.
T.53 N.
T.54 N.
T.55 N.
T.56 N.
T.57 N.
T.58 N.
T.59 N.
T.60 N.
T.61 N.
Twelfth Standard Parallel
Eighth Correction Line
Seventh Correction Line
Sixth Correction Line
Lake Winnibigoshish
Bow String lake
Round L.
Cut Foot Sioux L.
Cut Foot L.
Ball Club Lake
Deer Lake
Sturgeon Lake
Balsam
Wabana L.
DEER RIVER
COHASSET
GRAND RAPIDS
LA PRAIRIE
BLACKBERRY
BASS LAKE
DEER LAKE
SWAN RIVER
WAWINA
DULUTH

PLATE 65.


R A M I C O U N T Y
T. 151 N.
T. 152 N.
T. 153 N.
T. 154 N.
T. 155 N.
T. 156 N.
T. 157 N.
T. 158 N.
T. 159 N.
T. 160 N.
Thirteenth Standard Parallel
Fourteenth Standard Parallel
O N T A R I O
Longue Sault Rapids
Manitou Rapids
Third Guide Meridian
Tenth
Ninth Correction Line
Correction Line
Rainy River
HANNAFORD
FORT FRANCES
Koochiching
Rat Root River
Rainy Lake
BOIS FORT
Net Lake
62 N.
T. 63 N.
T. 64 N.
T. 65 N.
T. 66 N.
T. 67 N.
T. 68 N.
T. 69 N.
T. 70 N.
T. 71 N.
C O U N T Y

distinct moraine has been noted in this locality, in Itasca county, but further east, in St. Louis county, the Vermilion moraine seems to approach Rainy lake. It appears that that moraine may have been coincident with a stage of lake Agassiz, and ceases to be visible at the point where one of its beaches makes its appearance.

Still another glacial episode of Itasca county has to be noted. After the Lake Superior glacier lobe had shrunken, there was a period when its northern margin crossed the county about along the Mesabi range, forming a continuous morainic belt, which is well known between Grand Rapids and Pokegama falls and westward, extending across Cass county south of Leech lake. It has not been connectedly traced, but it probably blends with some of the morainic deposits that turn southwest and south in the central or western part of Cass county. This ice-lobe set back the whole upper Mississippi river, forming a large glacial lake covering Leech, Winnibegoshish, Cass and Bemidji lakes. It was but the enlarged descendant of the small lake noted at the headwaters of the Mississippi by Mr. Todd (Beltrami county) and had a history like that of other glacial lakes, finding lower and lower outlets as the glacier receded. Besides the outlets mentioned by Mr. Todd, viz., that westward from lake Itasca, that (probable) *via* the Clearwater river, and that to Red lake through the valley in which lies lake Julia, there is another into Bowstring lake in Itasca county, through which even yet, in time of high water, canoes can be paddled, without stopping, from the Mississippi into the Bowstring waters and thence to Lake of the Woods. But the most important and probably the longest continued of these outlets was that southwestward from Leech lake, through the channel occupied by the chain of lakes in Hubbard county.

This glacial lake has not been named. It has never been mentioned before except in a footnote in volume iv, p. 88, by the writer. It is now proposed to call it *lake Nicollet*, from the great geographer of Minnesota.

This county is yet almost wholly in its primeval condition. But few roads cross it. It is covered with almost continuous forest, including much pine, but very largely of deciduous trees. It is destined to constitute one of the richest portions of the state. Its forests, water-powers and its prospective mining give it high promise.

N. H. W.

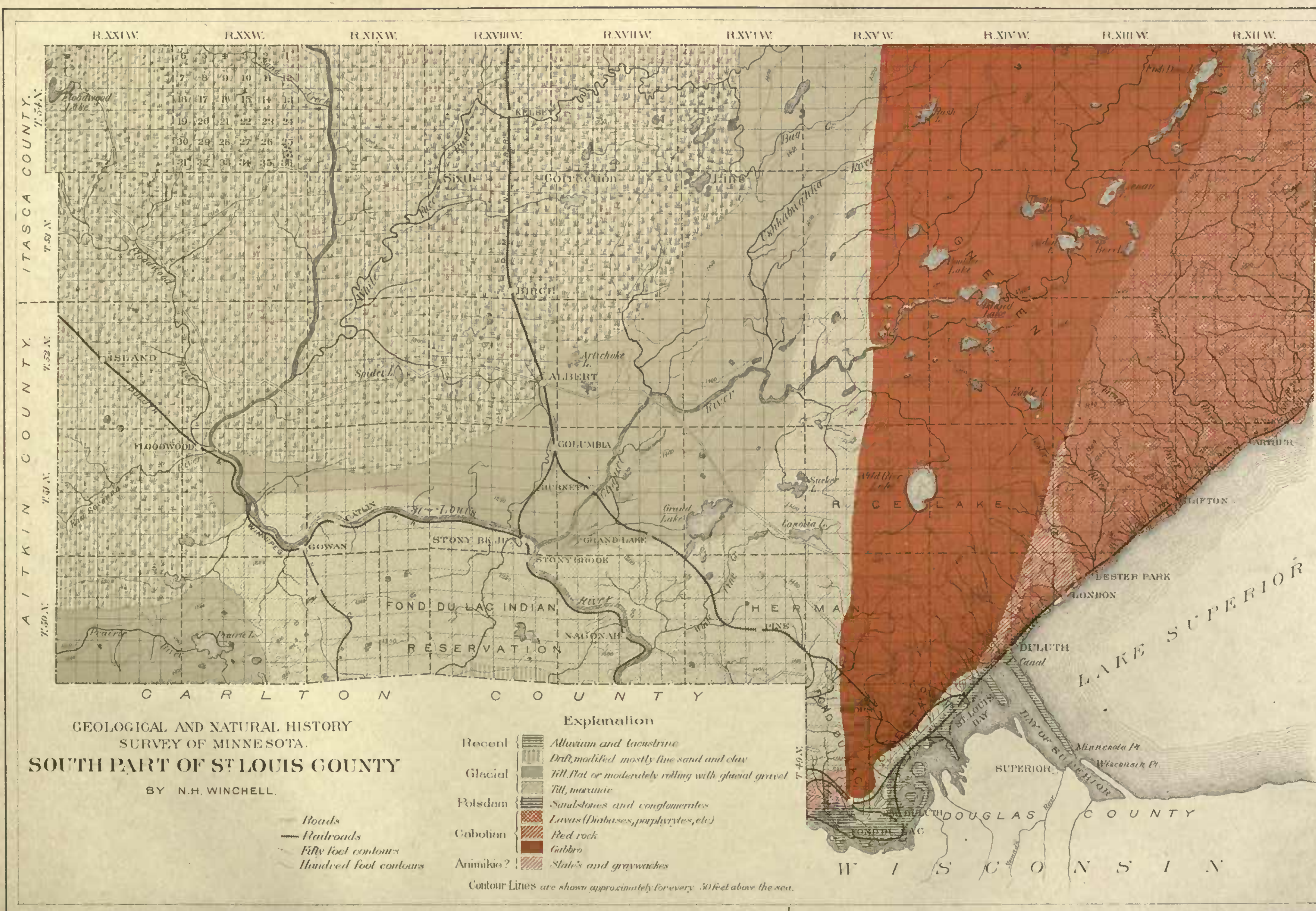
PLATE LXVI.

SOUTH PART OF ST. LOUIS COUNTY, 1899. N. H. WINCHELL.

The oldest rocks in the area of this plate, geographically known as the Thomson slates, are those seen in small scattered outcrops in the valley of the St. Louis river, in towns 50–17, 51–18 and 51–19. These probably belong to the Keewatin, while those seen in town 49–15 are supposed to be of the Animikie. Overlying these rocks is a nonconformable, coarse conglomerate (Puckwunge) seen in the valley of the St. Louis river at the water's edge in sec. 1, T. 48–16, just outside of the area of this plate. This is the bottom of the Potsdam and was followed by Manitou eruptive action in the near vicinity, as evinced by the nature of the fine conglomerates and sandstones that overlie it, although none of those traps are seen here interbedded with those sandstones. They are supposed to lie further south and east, covered by the alluvium of the St. Louis river and by lake Superior. In the area of this plate these Manitou eruptives are represented by the diabase dikes that cut the older (Cabotian) traps seen at Duluth and along the shore further east, as far as to Splitrock river.

Between Short Line park and Duluth the gabbro shows diabasic characters, and is believed to contain both the Beaver Bay diabase and the gabbro proper, the former being a great surface flow derived from the latter; the surface lavas at Duluth being still more remote effusives and perhaps considerably later than the gabbro, but all antedating the Puckwunge conglomerate.

One of the moraines of the Lake Superior ice-lobe, named Highland moraine by Mr. Elftman, passes through this area. It lies south of the Cloquet river and is crossed by the St. Louis river between Gowan and the Carlton county line, but extends into Carlton county, and Aitkin county south of Sandy lake. At the time of the formation of this moraine the ice dammed back the waters of the upper St. Louis river, forming a glacial lake which covered the great swamp that occupies the northwestern half of this area, extending also much further north and east. This was the infant progenitor of lake Superior. It had its outlet westward into the Mississippi, probably by way of the valleys of the East and West Savanne rivers, across a low divide, which later was the route of the Hudson Bay company's fur traffic for many years. Throughout the area of this old lake the till is covered either with laminated clays or with washed sands. This glacial lake has likewise never been named. In recognition of the faithful and indefatigable service of one of the assistants on the Minnesota survey in the glacial geology of the state, it is proposed to call this *lake Upham*. That the waters that laid the stratified clays of this district derived their sediments from the red shales and sands of the Lake Superior basin,


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
SOUTH PART OF ST LOUIS COUNTY
BY N.H. WINCHELL.
Roads
Railroads
Fifty foot contours
Hundred foot contours
Explanation
Recent — Alluvium and lacustrine
Glacial — Drift, modified mostly fine sand and clay
Till, flat or moderately rolling with glacial gravel
Till, morainic
Potsdam — Sandstones and conglomerates
Cabotian — Lavas (Diabases, porphyrites, etc)
Red rock
Gabbro
Animikie? — Slates and graywackes
Contour Lines are shown approximately for every 50 feet above the sea.
AITKIN COUNTY.
ITASCA COUNTY.
CARLTON COUNTY
LAKE COUNTY
DOUGLAS COUNTY
WISCONSIN
LAKE SUPERIOR
R.XXI W.
R.XX W.
R.XIX W.
R.XVIII W.
R.XVII W.
R.XVI W.
R.XV W.
R.XIV W.
R.XIII W.
R.XII W.
T.54 N.
T.53 N.
T.52 N.
T.51 N.
T.50 N.
T.49 N.
FOND DU LAC INDIAN RESERVATION
HERMAN
RICE LAKE
FLOODWOOD
ISLAND
BIRCH
ALBERT
COLUMBIA
BURNETT
GOWAN
STONY BR. JN.
GRAND LAKE
STONY BROOK
NAGONAB
KELSEY
Sixth
Correction
Line
DULUTH
Canal
LESTER PARK
LONDON
CLIFTON
SUPERIOR
ST LOUIS BAY
BAY OF SUPERIOR
Minnesota Pt.
Wisconsin Pt.
FOND DU LAC
St. Louis
River
White
Floodwood
Prairie
Artichoke L.
Spider L.
Grand Lake
Sucker L.
Wild Rice Lake
Cokato L.
Rush L.
Boulder Lake
Island Lake
Eagle L.

carried westward by the Lake Superior ice-lobe, is evident from the copper-colored drift seen along the upper waters of the St. Louis, below Embarras lakes, where a red, pebbly clay is the last drift deposit. At the mouth of the East Savanne river it is red laminated clay. Red drift, in a general morainic form, continues thence southwestwardly on the east side of the Mississippi, south of Sandy lake and north of lake Mille Lacs, to the mouth of the Pine river, in Cass county. This moraine is crossed, or trenched, at least, by the Mississippi between Pine river and the French rapids, a short distance above Brainerd. The Mississippi river and its northern tributaries were more or less dammed back by this moraine, causing lake Aitkin, described by Mr. Upham at Aitkin (Plate LVII). It also appears that the Mississippi was forced into a general southwestward direction, between Sandy lake and the mouth of the Crow Wing river, by this ice-lobe.

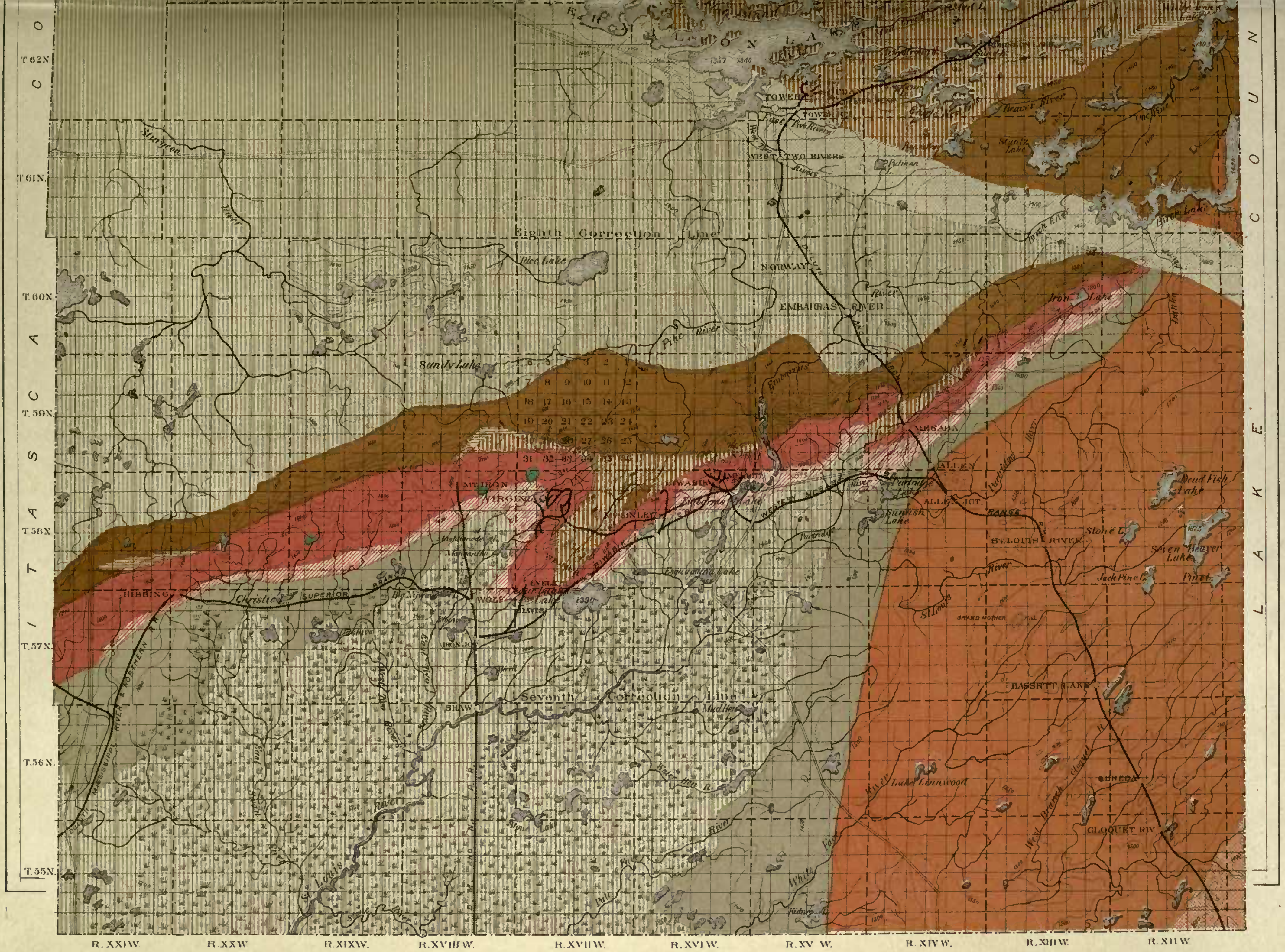
The region covered by lake Upham is still one of extensive swamp, with much peat. Its beach lines have not been traced out, and it is quite likely they cannot be continuously located, owing to the fluctuating level which the lake probably maintained. N. H. W.

PLATE LXVII.

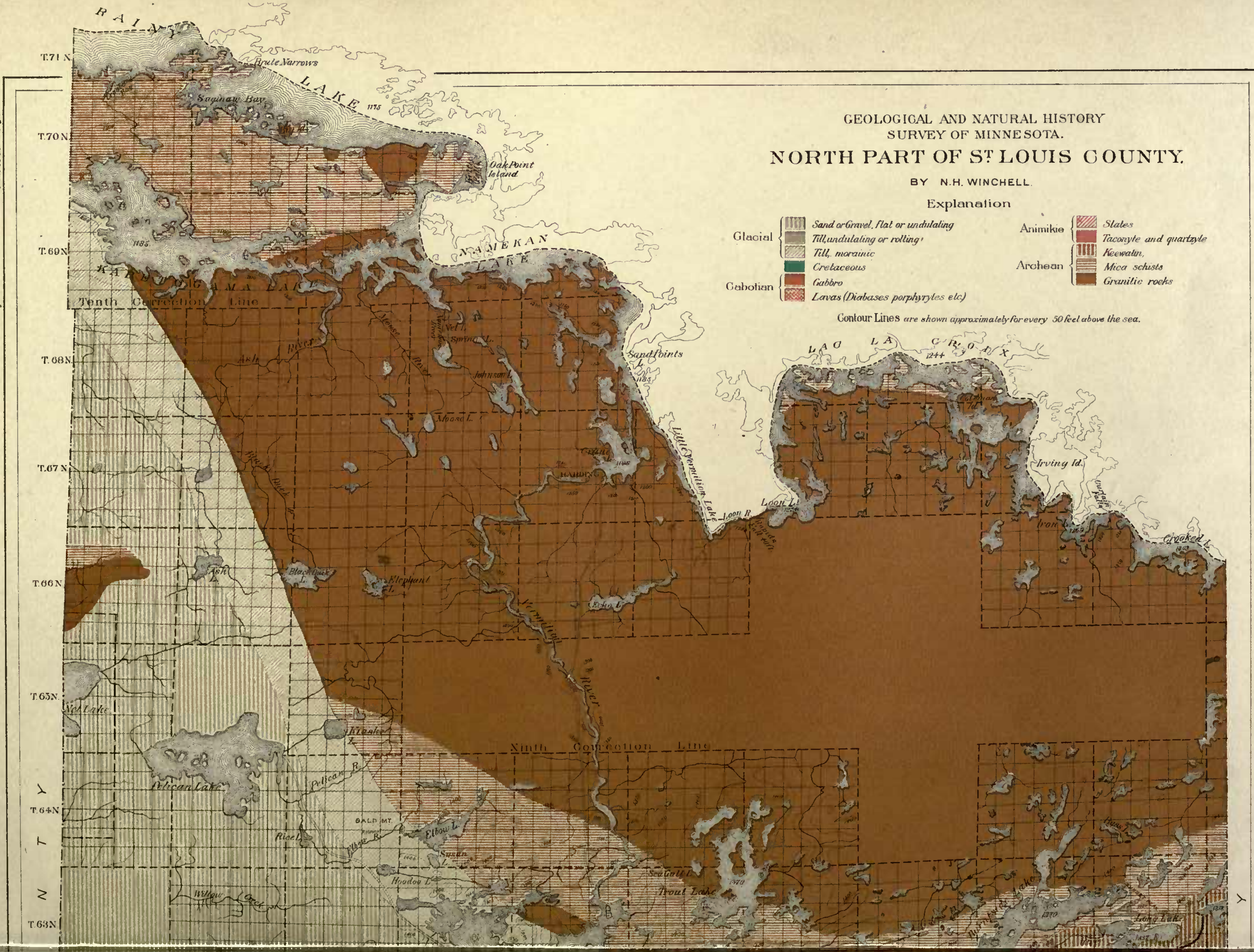
THE NORTH PART OF ST. LOUIS COUNTY, 1899. N. H. WINCHELL.

This area is crossed from northeast to southwest by the Giant's range of granite, and is entered by the Mesabi range of gabbro from the northeast at a point about two and a half miles south from the entrance of the Giant's range. The Mesabi range does not continue on its westward course but veers off more southerly, and is lost, as a "range," in the general upland which is drained by the headwaters of the Cloquet and the St. Louis rivers. The same rocks appear again on some of the branches of the Cloquet and at Duluth. Owing to the fact that the earliest developments of iron ore were on the northern slopes of Mesabi range, that name was given to the southern iron ore range, and it has been continued westwardly, although the iron-bearing rocks, in their westward extension, lie on the southern flank of the Giant's range and are far separated from the Mesabi range proper.

Between the Giant's range and the Mesabi range, in the angle formed by their divergence, is an expanse of flat and largely swampy land, which was formerly occupied by the glacial lake Upham, as explained in connection with Plate LXVI. Eastward from that flat land, and, indeed, in all directions, the drift-covered surface rises gently, at first mainly flat, but becoming rough and morainic. On the gabbro area this roughness is due in part also to the irregularity of the rocky contour, and it surrounds some large muskegs, such as are crossed by the Duluth and Iron Range railroad. Northward from lake Upham a distinctly morainic tract follows approximately the course of the Giant's range, that range apparently being the barrier along which the Lake Superior ice-margin lay for a long time after the withdrawal of the continental margin toward the north. It is also likely that this moraine was at an earlier date the line of confluence of the two ice-lobes, as indicated by the alternation of northern and Lake Superior till deposits at various points on the Giant's range. The Embarras river maintained a southward discharge through this moraine, and wholly across the Giant's range, by way of the Embarras lakes, whereas the Pike river, rising on the Giant's range but five or six miles further west, flows northward to Vermilion lake. These streams formerly probably united in a glacial lake which incidentally must have extended eastward nearly to Birch lake, and which covered a large flat tract now drained by the Embarras river, characterized in places by laminated brick clay. Its outlet is crossed by the old portage leading from Pike river to Embarras river, in the southwestern part of T. 60-15, which is broadly terraced. The shores of this lake remain to be traced out. The lake itself might be



I T A S C A C O
L A K E C O U N
T.62N.
T.61N.
T.60N.
T.59N.
T.58N.
T.57N.
T.56N.
T.55N.
R.XXIW.
R.XXW.
R.XIXW.
R.XVIIIW.
R.XVIIW.
R.XVIW.
R.XV W.
R.XIVW.
R.XIIIW.
R.XIIW.
Eighth Correction Line
Seventh Correction Line
TOWER
WEST TWO RIVERS
NORWAY
EMBARRAS RIVER
MESABA
Sandy Lake
Rice Lake
Pike River
Birch Lake
Iron Lake
HIBBING
VIRGINIA
EVELETH
MCKINLEY
BIWABIK
SHAW
St. Louis River
Sunrise Lake
Stone L.
Dead Fish Lake
Seven Beaver Lake
Jack Pine L.
BASSETT LAKE
CLOQUET RIV.
West Branch Cloquet R.
Lake Linnwood
White Face River
Beaver River
Embarras R.
Partridge River
Dunka
Sturgeon River
Mud Hen L.
St. Louis
GRAND MOTHER HILL


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
NORTH PART OF ST. LOUIS COUNTY.
BY N.H. WINCHELL.
Explanation
Glacial
Sand or Gravel, flat or undulating
Till, undulating or rolling
Till, morainic
Cretaceous
Cabotian
Gabbro
Lavas (Diabases porphyrytes etc)
Animikie
Slates
Taconyte and quartzyte
Archean
Keewatin,
Mica schists
Granitic rocks
Contour Lines are shown approximately for every 50 feet above the sea.
RAINY LAKE
Brule Narrows
Saginaw Bay
Oak Point Island
NAMEKAN LAKE
KABETOGAMA LAKE
Tenth Correction Line
Ninth Correction Line
LAC LA CROIX
Sand Points L.
Little Vermilion Lake
Loon L.
Irving Id.
Crooked L.
Johnson L.
Moose L.
Elephant L.
Echo L.
Black Duck L.
Ash L.
Ash River
Vermilion River
Pelican Lake
Pelican R.
Net Lake
Kjostad L.
Elbow L.
Rice L.
BALD MT.
Susan L.
Hoodoo L.
Willow Creek
Trout Lake
Long Lake
T.71 N.
T.70 N.
T.69 N.
T.68 N.
T.67 N.
T.66 N.
T.65 N.
T.64 N.
T.63 N.

named *lake Norwood,* from Dr. J. G. Norwood, the first geologist who gave a description of this route to Vermilion lake.*

The Vermilion moraine seems to have marked the southern limit of the northern ice for a comparatively short period of time, and from it the ice margin apparently retreated rapidly, leaving but a slight drift sheet, the country toward the northeast being one which Nicollet designated one "of rocks and water."

In the area of this plate are the great iron mining developments of the state, viz., on the Vermilion Iron range at Tower and Ely, and on the Mesabi Iron range. The geology of the rocks and of the iron industry must be learned from volumes iv and v, as there is not space here even to give it in abstract. N. H. W.

*Geological report of a survey of Iowa, Wisconsin and Minnesota. D. D. OWEN, 1847-1850, pp. 311-314.

PLATE LXVIII.

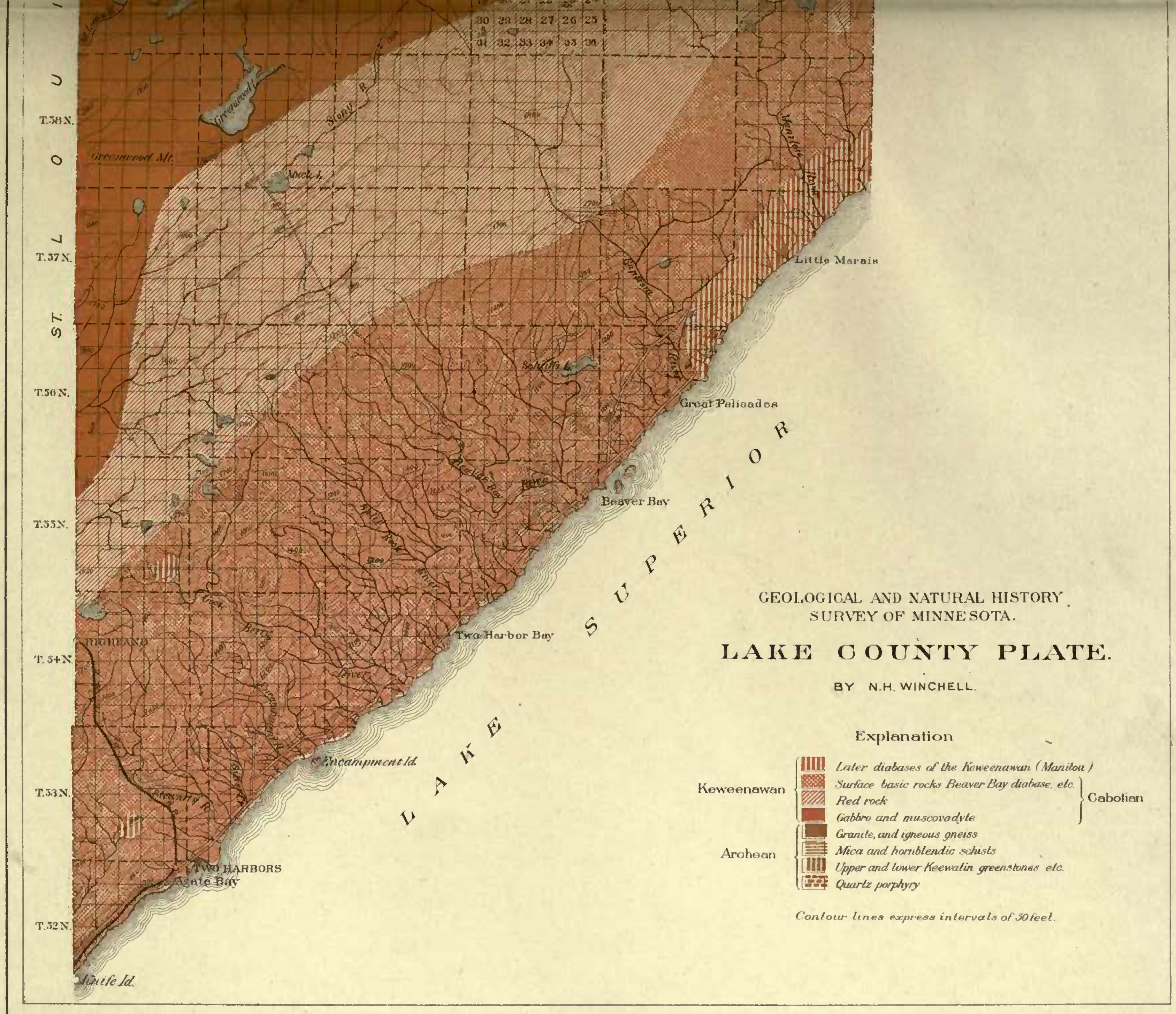
LAKE COUNTY, 1899. N. H. WINCHELL.

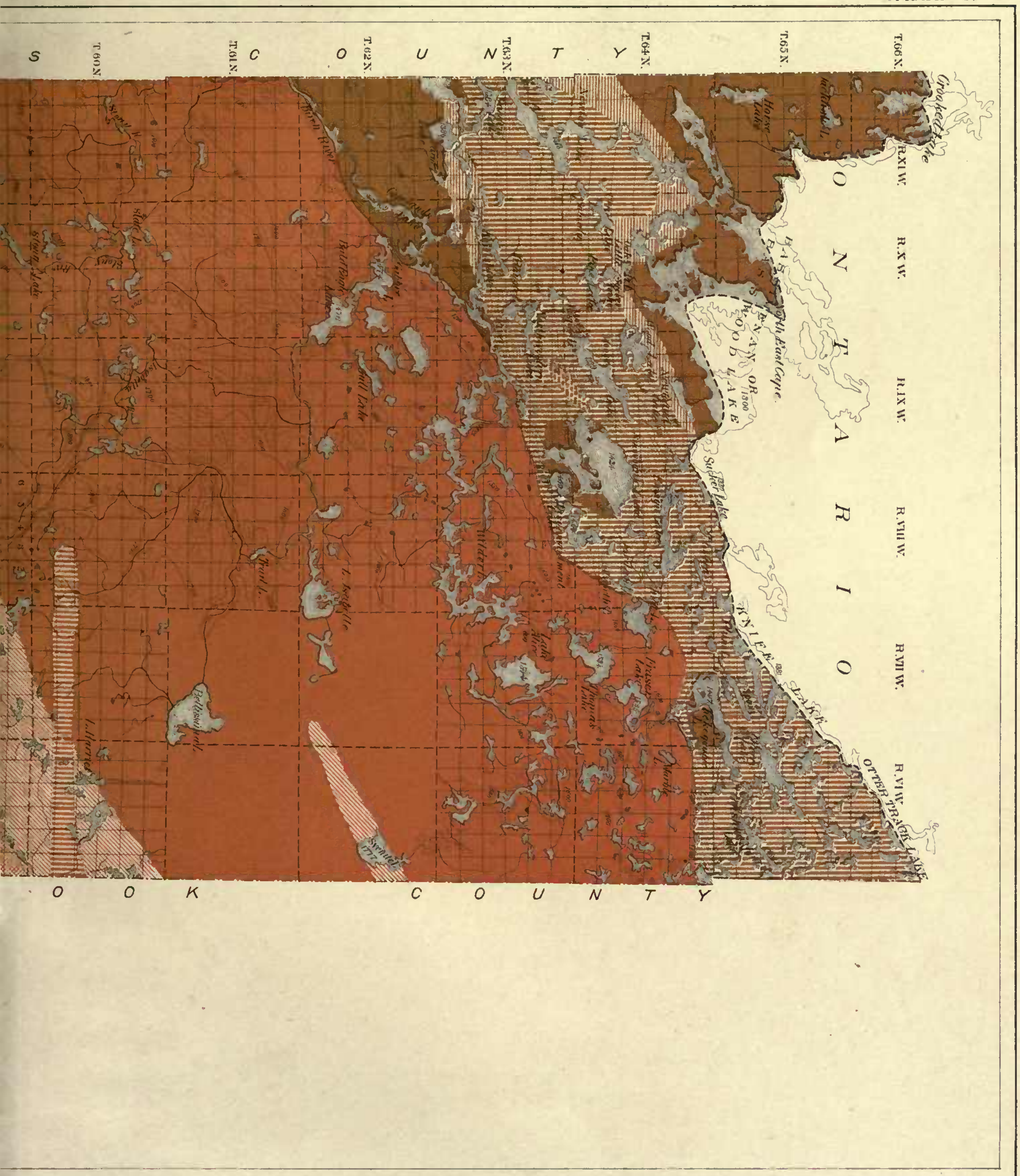
The highest portion of this county is in the region of the "red rock," 1,800 to 1,850 feet above the sea. Here is a broad, undulating plateau, generally deeply buried by morainic drift, from which nearly all the streams of the county take their source. Southward from this plateau are comparatively few lakes, but toward the north they are very numerous, and in the northern one-third part of the county they are so frequent and the streams are so large and steady that most of the travel is done by canoe. In this region of many lakes the drift is less abundant, and the general forms of the lakes are determined by the contours of the rocky substructure. They run mainly northeast and southwest, yet, in the area of the gabbro, their shapes and direction are more varied. The gabbro area in general rises higher than the Archean to the north, constituting the eastern extension of the Mesabi range. The Giant's range is not perceptible as an individual topographic element except in the northeastern part of the county, south of Ogishke Muncie lake, and here, instead of granite, the rock composing it is greenstone. Toward the southwest from this place the Giant's range merges into the Mesabi range and they continue together till reaching St. Louis county.

The Highland moraine runs across this county in a northeastward direction, having its greatest development in the region of the sources of the Manitou river. It is named from the railroad station in the southwestern part of this county which is situated in a deep recession on the south side of the moraine. This is joined by another morainic belt coming from the west, in the north part of T. 159-8, whose relations and extension are more or less obscure, although it has provisionally been correlated by Mr. Elftman with the Itasca moraine. It may be an eastward extension of the Vermilion moraine, more or less rewrought by the Lake Superior ice-lobe. It appears to be confluent westward with the Mesabi moraine.

The name lake Gabbro was given by Mr. Elftman to a glacial lake in this county covering the region of lake Isabella westward to Gabbro lake. Owing to an unfortunate duplication of this term, leading to confusion, it is proposed to change this name, according to the rule of priority well known in scientific nomenclature, to *lake Elftman*, in recognition of Mr. Elftman's discovery and first description.

Still another well-marked glacial lake, *lake Dunka*, formed by the retreating ice from the Vermilion moraine, covered the region of Birch lake. It had its outlet into the valley of the Embarras river, and during a part of its existence into lake Norwood, which covered the upper valley of the Embarras in glacial time. This


GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
LAKE COUNTY PLATE.
BY N.H. WINCHELL.
Explanation
Keweenawan
Later diabases of the Keweenawan (Manitou)
Surface basic rocks Beaver Bay diabase, etc.
Red rock
Gabbro and muscovadyte
Cabotian
Archean
Granite, and igneous gneiss
Mica and hornblendic schists
Upper and lower Keewatin greenstones etc.
Quartz porphyry
Contour lines express intervals of 50 feet.
LAKE SUPERIOR
ST. LOUIS
T.58 N.
T.57 N.
T.56 N.
T.55 N.
T.54 N.
T.53 N.
T.52 N.
Greenwood Mt.
Greenwood L.
Stony R.
Little Marais
Great Palisades
Beaver Bay
Two Harbor Bay
Encampment Id.
TWO HARBORS
Agate Bay
Knife Id.
HIGHLAND


T.60N.
T.61N.
T.62N.
T.63N.
T.64N.
T.65N.
T.66N.
R.XI W.
R.X W.
R.IX W.
R.VIII W.
R.VII W.
R.VI W.
ONTARIO
S C O U N T Y
O O K C O U N T Y
KNIFE LAKE
OTTER TRACK LAKE
Sucker Lake
North East Cape
Crooked Lake

lake was probably only a lake-like expansion of an important drainage course, at first along the southern border of the continental ice, similar in outline to the present connected lakes which are formed by the Kawishiwi river from lake Isabella to Garden lake. Thus the upper Kawishiwi river, gathering its waters first into lake Elftman, escaped into lake Dunka, and thence over a low divide passed into lake Norwood. By this stream was excavated the deep channel through the Mesabi moraine at the Embarras lakes. The stream then entered lake Upham, and further south lake St. Louis of Carlton county, and discharged into the Mississippi by way of the Moose and Kettle rivers. This must have been the course of glacial drainage from the interlobate area between the continental, or northern, ice margin and that of the Lake Superior ice-lobe, as the two lobes successively uncovered greater and greater areas toward the northeast, the areas first uncovered being continually the highest, and the medial moraine left by them being the Itasca and Mesabi moraines. There remains yet much to be done to work out the details of this grand retreat.

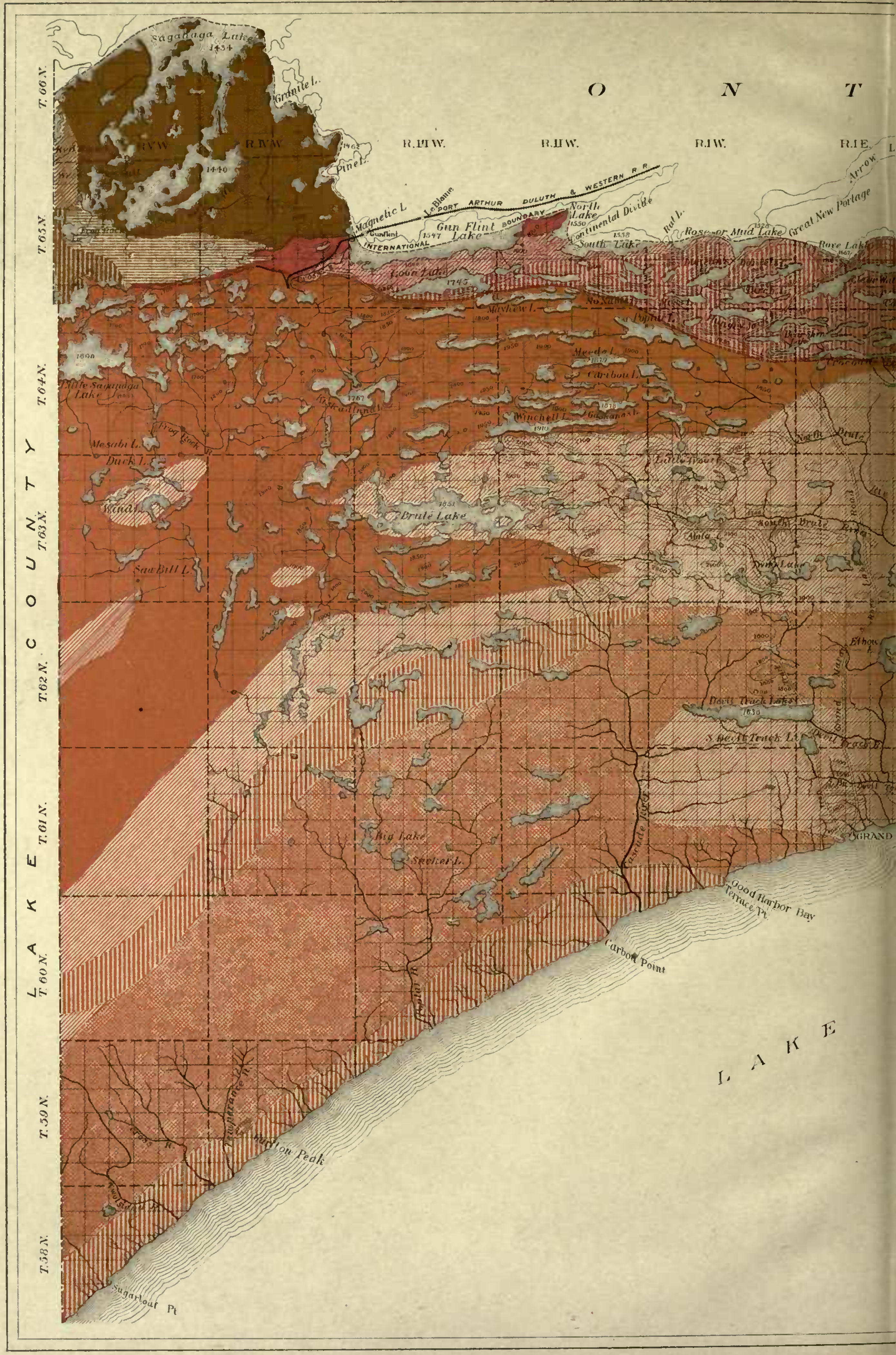
This region is naturally one of forest, mainly coniferous, but fires have swept off the primeval forest and lumbermen have taken much of the pine that remained.

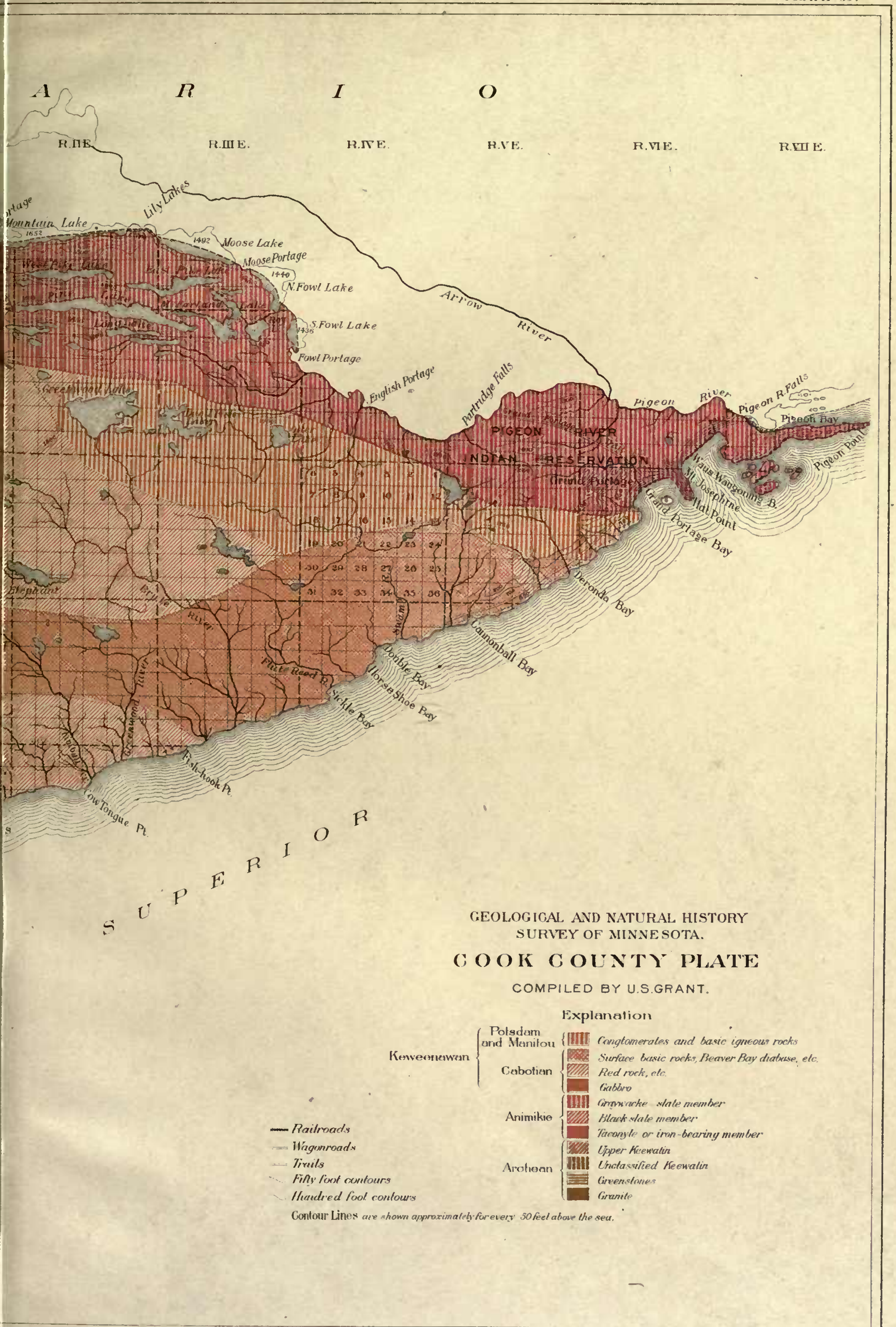
N. H. W.

PLATE LXIX.

COOK COUNTY, 1899. U. S. GRANT.

The surface of this county is rough and hilly, but is divided into more or less evident and continuous ridges and valleys that extend, with the strike of the underlying rocks, east and west in the north, and more northeast and southwest in the south. This is a feature that becomes more and more pronounced toward the east, and almost fades out toward the west. Besides this east-and-west trend of the minor topography there are greater contours which also run in the same direction, viz.: (a) The lakeward slope, from two to four miles wide, which descends abruptly from 200 to 500 feet from the summits of the Sawteeth mountains to the level of lake Superior. In the hill range which limits this slope on the north are Carlton peak and mount Josephine, the former 927 feet and the latter 703 feet above lake Superior. The summits of this hill range show, when viewed from the east, a singular serrate outline, and hence the name Sawteeth mountains. This range is composed primarily of the Beaver Bay diabase. (b) The belt of the Highland moraine and attendant gravels, which is comparatively smooth, whether considered as a morainic surface or a rock formation. This extends to a line which runs approximately from the Pigeon river a few miles south of South Fowl lake to the vicinity of Elephant lake, and thence a little south of west to the west line of the county. North of this is (c) the range of the Misquah hills, containing the highest land in the state (2,230 feet), composed mainly of red granitic rock. This belt, as a topographic feature, does not entirely cross the county, but fades out toward the east, and turns toward the southwest toward the west. This range contains also the peaks known as Brulé and Eagle mountains. (d) Northward from the belt of red rock is a belt of gabbro, which is less rough, but consists of massive east-west swells alternating with flat tracts. These alternations appear to be due to the projection of gabbro sills into the Animikie, the Animikie itself being hid by the accidents of the intrusion and by surface materials. This belt is not continued to the Pigeon river, but runs to a point in T. 64-1 E. (e) Next north of this is the Animikie province, which is probably the same in substructure as the last, but differs in having the Animikie with its intrusive sills separately identifiable. Here the Animikie exists in the form of monoclines from 100 to 500 feet high, dipping to the south. The northward face of each hill is steep, even nearly vertical, capped by one of the sills of igneous rock, while the southward slope is gradual, and usually consists, but not invariably, of the upper surface of the igneous rock. These monoclines are sometimes five to eight miles long, but they are grouped *en echelon*, overlapping at each end. In the valleys between them are the


O N T
L A K E C O U N T Y
T. 66 N.
T. 65 N.
T. 64 N.
T. 63 N.
T. 62 N.
T. 61 N.
T. 60 N.
T. 59 N.
T. 58 N.
R.IV W.
R.III W.
R.II W.
R.I W.
R.I E.
Saganaga Lake
1434
Granite L.
Pine L.
Magnetic L
PORT ARTHUR DULUTH & WESTERN R R
INTERNATIONAL BOUNDARY
Gun Flint Lake
1547
North Lake
Continental Divide
South Lake
Rat L.
Rose or Mud Lake
Great New Portage
Arrow
Rove Lake
Mayhew L.
Poplar L.
Meeds L.
Caribou L.
Winchell L.
Little Saganaga Lake
Frog Rock R.
Mesabi L.
Duck L.
Brulé Lake
Saw Bill L.
North Brule
South Brule
Devil Track Lake
S. Devil Track L.
Big Lake
Sucker L.
GRAND
Good Harbor Bay
Terrace Pt.
Carbon Point
Temperance R.
Cross R.
Sugarloaf Pt.
L A K E


A R I O
R.II E.
R.III E.
R.IV E.
R.V E.
R.VI E.
R.VII E.
Lily Lakes
Mountain Lake
Moose Lake
Moose Portage
N. Fowl Lake
S. Fowl Lake
Fowl Portage
Arrow River
English Portage
Partridge Falls
Pigeon River
Pigeon R. Falls
Pigeon Bay
Pigeon Pt.
PIGEON RIVER
INDIAN RESERVATION
Grand Portage
Waus Wagouing B.
Mt. Josephine
Hat Point
Grand Portage Bay
Deronda Bay
Cannonball Bay
Double Bay
Horse Shoe Bay
Sickle Bay
Flute Reed R.
Fish-hook Pt.
Cow Tongue Pt.
Brule River
Greenwood River
SUPERIOR
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
COOK COUNTY PLATE
COMPILED BY U.S.GRANT.
Explanation
Keweenawan
Potsdam and Manitou
Conglomerates and basic igneous rocks
Cabotian
Surface basic rocks, Beaver Bay diabase, etc.
Red rock, etc.
Gabbro
Animikie
Graywacke - slate member
Black slate member
Taconyte or iron-bearing member
Archean
Upper Keewatin
Unclassified Keewatin
Greenstones
Granite
Railroads
Wagonroads
Trails
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.

remarkable elongated lakes of the region. From this Animikie province the surface suddenly descends to the Archean, about 500 feet. This is seen, in this county, at Gunflint lake. Further east the north limit of the Animikie runs into Ontario. Mount Reunion is one of the most remarkable of these monoclines. It is at the south shore of Rove lake on the international boundary. (f) The Archean topography appears in Lake county at the west end of Gunflint lake, and is characterized by the Giant's range (of granite) which extends from there into Lake county, although the composing rock toward the west is greenstone. N. H. W.

PLATE LXX.

POKEGAMA LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

The rock at Pokegama falls is a quartzyte, dipping southerly. It also appears on Prairie river, at the lower falls. Above Pokegama falls, about a quarter of a mile, it forms a vertical bluff on the right bank, exposing in all about twenty-five feet of the bedding. This rock has been uniformly supposed to lie below the iron ore horizon of the Mesabi range. There is a coarse quartzose sandstone seen below the ore at the Cincinnati mine near Biwabik, and also below the ore on the Gogebic Iron range (Aurora mine), and the Pokegama rock has been parallelized with that horizon. That is the view presented in most of the reports of the survey (except volume v, page 992), but there are facts that indicate that it is above rather than below the ore.

1. In descending Prairie river, at the lower falls this rock appears to dip southerly and to run below the taconyte seen there, but the superposition is not seen. There is a break in the continuity of observation north of the strike of the ore-bearing rock sufficiently broad to allow space for a synclinal which might throw the iron ore under the quartzyte.

2. The rock becomes conglomerate in irregular patches. The pebbles then contained in it are such that they cannot all have come from the Archean, viz., red quartz-porphyry, diabase, pumice, very fine kaolinic debris, both white and red, hornstone, flint, like that at Gunflint lake, micaceous slate, white and lavender quartz, green schist and red shale, resembling catlinite. The rock is essentially a quartz conglomerate.

3. It is overlain by a fine, unctuous shale, which is red, but is streaked with white by reason of sedimentation.

4. Where the Diamond mine exploration was made, a few miles further east, the ore, which is in the upper part of this quartzyte, is not taconitic. It is limonitic rather than hematitic. No ore is known there of the character and quality of that at the lower falls of Prairie river.

This conglomerate, therefore, seems to contain Keweenawan and Animikie as well as Archean debris. It may be of the age of the Puckwunge (Potsdam) sandstone and conglomerate. The overlying unctuous shale may be of the Keweeuawan, similar to that seen along the banks of the St. Louis river above Fond du Lac, or of the Cretaceous, appearing more like the latter. If it should prove to be Cretaceous that would suggest the same age for the quartzyte. The preponderance of evidence at present is toward the Puckwunge (Potsdam) age of this quartzyte.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

POKEGAMA LAKE PLATE

COMPILED BY U.S. GRANT.

Roads and Trails
Railroads
Fifty foot contours
Hundred foot contours

Explanation

Glacial { Till flat or undulating and modified drift; Till knolly and hilly, terminal moraine
Animikie { Taconyte or iron-bearing member; Pokegama quartzyte
Archean { Granitic rocks

Contour Lines are shown approximately for every 50 feet above the sea.

The moraine that crosses the Mississippi between Pokegama falls and the mouth of Prairie river is supposed to be of composite nature and origin, having originated as a median accumulation between the northern, continental, ice and the Lake Superior lobe. There is some Cretaceous debris in the gravel banks, and along the river shore, and occasionally a piece of northern limestone among the boulders. Glacial striæ also run in a general northwest and southeast course, or more nearly north and south. It is therefore probable that the margin of the Lake Superior lobe had but little agency in the production of the moraine as it now exists between Pokegama falls and Grand Rapids. Sufficient examination has not been made to determine the nature of this morainic belt. N. H. W.

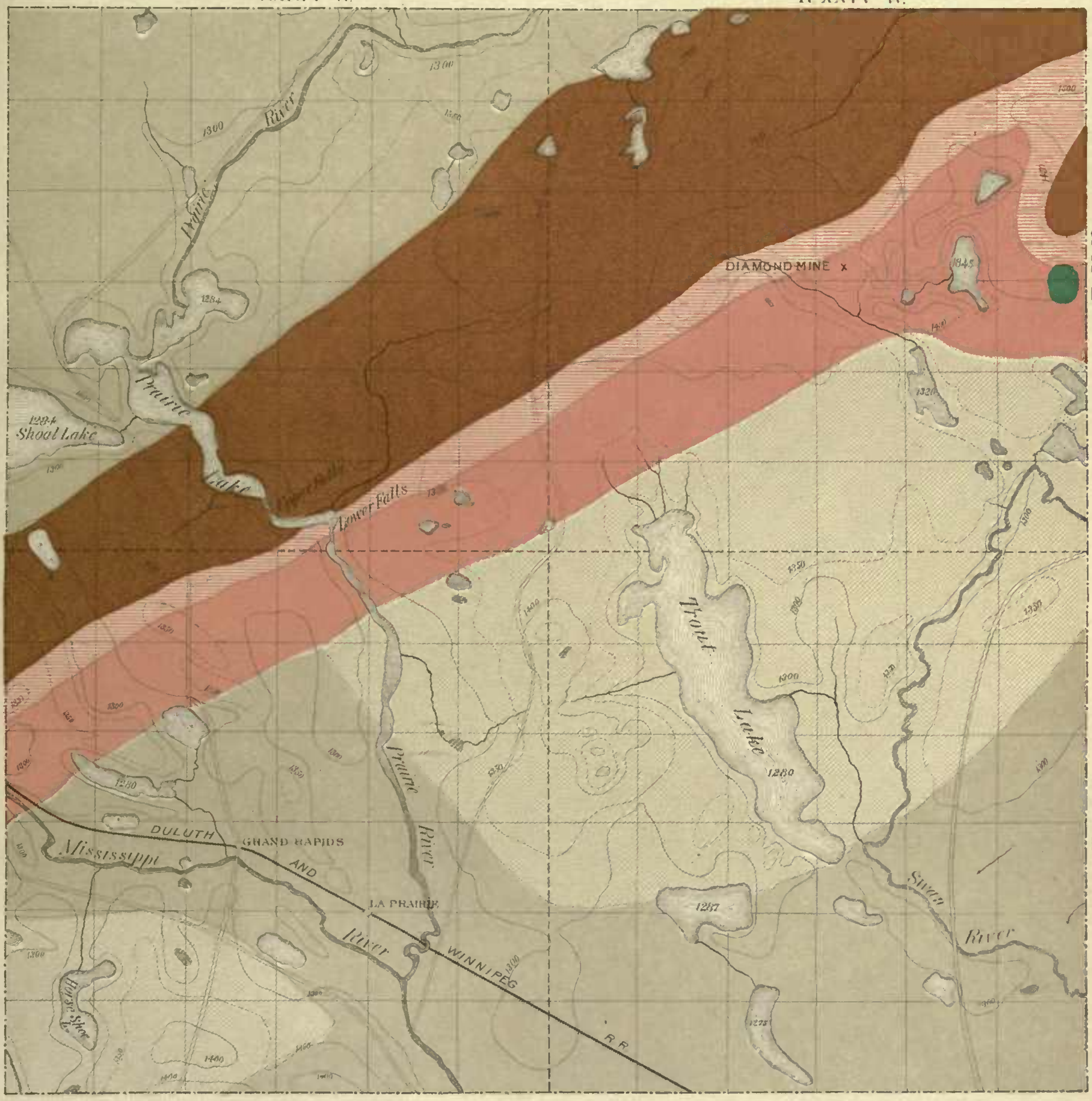
PLATE LXXI.

GRAND RAPIDS PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

The geology of this plate is similar to that of Plate LXX, and has been presented in the last chapter. The facts as to the quartzyte are there given, going to show that this quartzyte, so far as it appears at Prairie River falls, is not a part of the Animikie. There may be another quartzyte or sandstone belonging below the taconyte, which extends eastward, as represented on this and other plates of the Mesabi range, and this may be that which is mentioned by Mr. Grant in a boulder-strewn belt lying between the outcropping quartzyte and the granite (figure 61, p. 352, vol. iv), evidences of which are not wanting on the Mesabi range further east. If so, these two quartzytes could not be considered parts of the same formation. They may be accidentally brought together at Prairie River falls, but between them must be an interval in which belongs the Animikie and the Cabotian epoch of the Keweenawan. From this it would also follow that the Pokegama quartzyte at Pokegama falls is no guide as to the direction of strike of the Animikie and the iron ore, but that the ore might run much further south, and might exist under considerable thickness of that quartzyte.

The iron ore from the Arcturus mine, in nineteen analyses, gave an average of 61.26 of metallic iron, with phosphorus at .037. This mine is situated near the eastern limit of this area, secs. 13 and 24, T. 56–24.

The Cretaceous is found in the test pits of the Arcturus Iron company. It is highly fossiliferous. N. H. W.



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

GRAND RAPIDS PLATE

COMPILED BY U. S. GRANT

Roads
Railroads
Fifty foot contours
Hundred foot contours

Explanation

Glacial	*Till, flat or undulating, and modified drift*
	Till, knolly and hilly, terminal moraine
Cretaceous	*Shales, conglomerate, etc.*
Animikie	*Taconyte or iron-bearing member*
	Pokegama quartzyte
Archean	*Granitic rocks*

Contour Lines *are shown approximately for every 50 feet above the sea.*

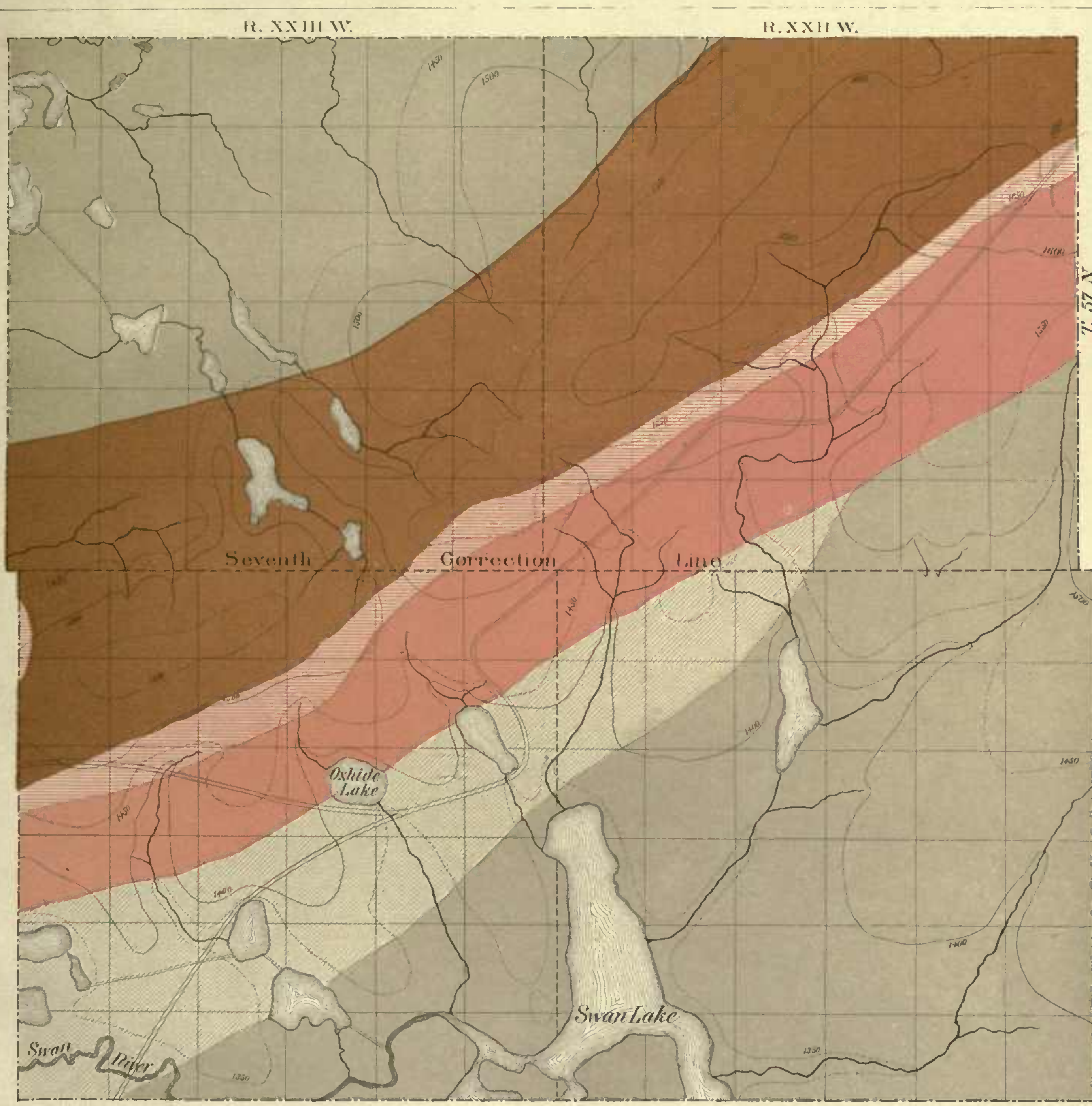
PLATE LXXII.

SWAN LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

The strike of the most elevated part of the country represented by this plate is occupied by the granite of the Giant's range. So far as known it is of a general light color, or reddish gray, but a dark, hornblendic rock, one of the phases of the Archean, is said to occur in sec. 25, T. 57–23. The Animikie, so far as known, consists of only the quartzyte and taconyte members. In a drill-hole made in the northeastern part of sec. 1, T. 56–23, the taconyte was found to be 231 feet in thickness, containing seams and bands of lean ore. Under the taconyte was quartzyte, which was penetrated four and a half feet.

The iron ore of the Mesabi Chief mine was one of the first bodies of ore discovered within the area of this plate, situated S. W. ¼ sec. 23, T. 57–22. N. H. W.

PLATE 72.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

SWAN LAKE PLATE

COMPILED BY U.S.GRANT.

Explanation

Glacial { *Drift, unstudied*
Drift, probably morainic

Animikie { *Taconyte or iron-bearing member*
Pokegama quartzyte

Archean { *Granitic rocks*

Roads
Fifty foot contours
Hundred foot contours

Contour Lines *are shown approximately for every 50 feet above the sea.*
Data for contour lines are very imperfect.

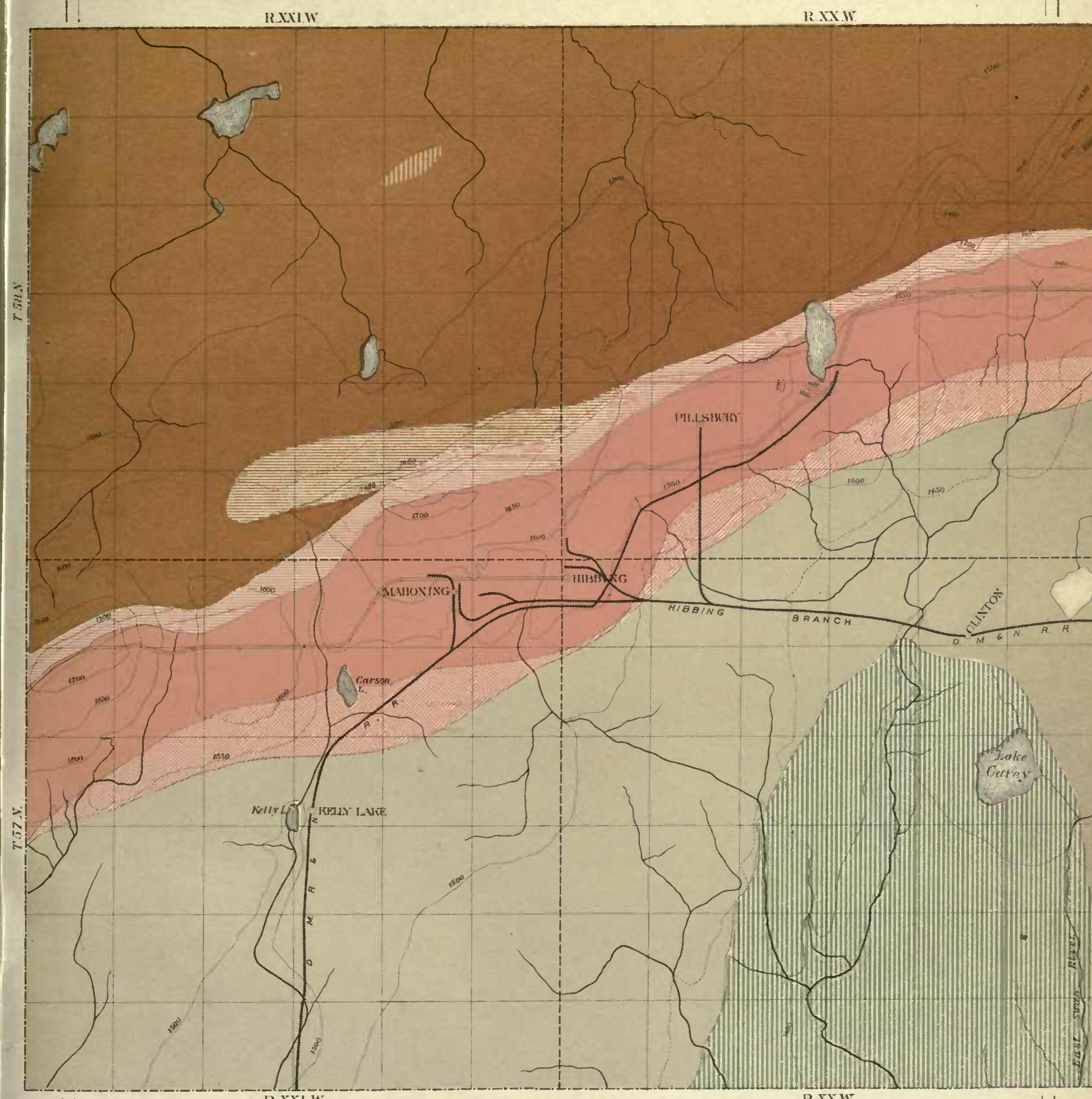
PLATE LXXIII.

Hibbing Plate of the Mesabi Iron Range, 1899. N. H. Winchell.

The granitic portion of the Archean here shows a variation. It is rather a dark schist, or sometimes dioritic, containing hornblende. This schistose rock is supposed to be derived from the Keewatin by metamorphism. Also, in sec. 11, T. 58-21, has been found an area of greenstone, but its size is not known. It is probably much larger than is represented on this plate. Overlying the Archean is the Animikie, consisting here of three members, viz., quartzyte, taconyte and black slate. The quartzyte member is sometimes very scant or wanting, allowing the iron-bearing rocks to lie directly on the Archean. The iron-bearing rocks are very productive in the central part of this area. Here ore is shipped from mines at Mahoning, Hibbing and Pillsbury.

Mr. J. E. Spurr, from samples collected in sec. 22, T. 58-20, and from other localities, derived the conclusion, which has been verified by later examinations, that the ore of the Mesabi Iron range is due to an alteration of a peculiar greensand, which he likened to foraminiferal glauconite. This sand was deposited originally in the shallow water of the ocean along the Taconic shore line, not far from the Archean land area, and it took the sedimentary bedding which is yet plainly visible in much of the taconyte rock and in the ore itself. The changes in this greensand gave rise chiefly to silica, oxide of iron, and small amounts of actinolite. When atmospheric air, or carbonated waters, had free access to this sand, its iron sometimes took the form of siderite.

The writer fully accepts this view of the origin of the Mesabi ore, but does not believe that the greensand was of foraminiferal origin. The reasons for believing that the greensand was originally a volcanic glass-sand of a very basic nature are too complicated and technical to be even summarized in any satisfactory manner in this atlas. They are given in Part III of volume v of this report, much of the microscopical evidence being in Part II of the same volume. N. H. W.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

HIBBING PLATE

BY N.H. WINCHELL.

Explanation

- Modified drift
- Glacial drift. Till
- Taconic: Black slates, Taconyte, Qurtzyte — Animikie
- Archean: Granite, Post Keewatin; Mica schists, Keewatin; Greenstones

- Railroads
- Wagonroads
- Fifty foot contours
- Hundred foot contours

Contour Lines are shown approximately for every 50 feet above the sea.

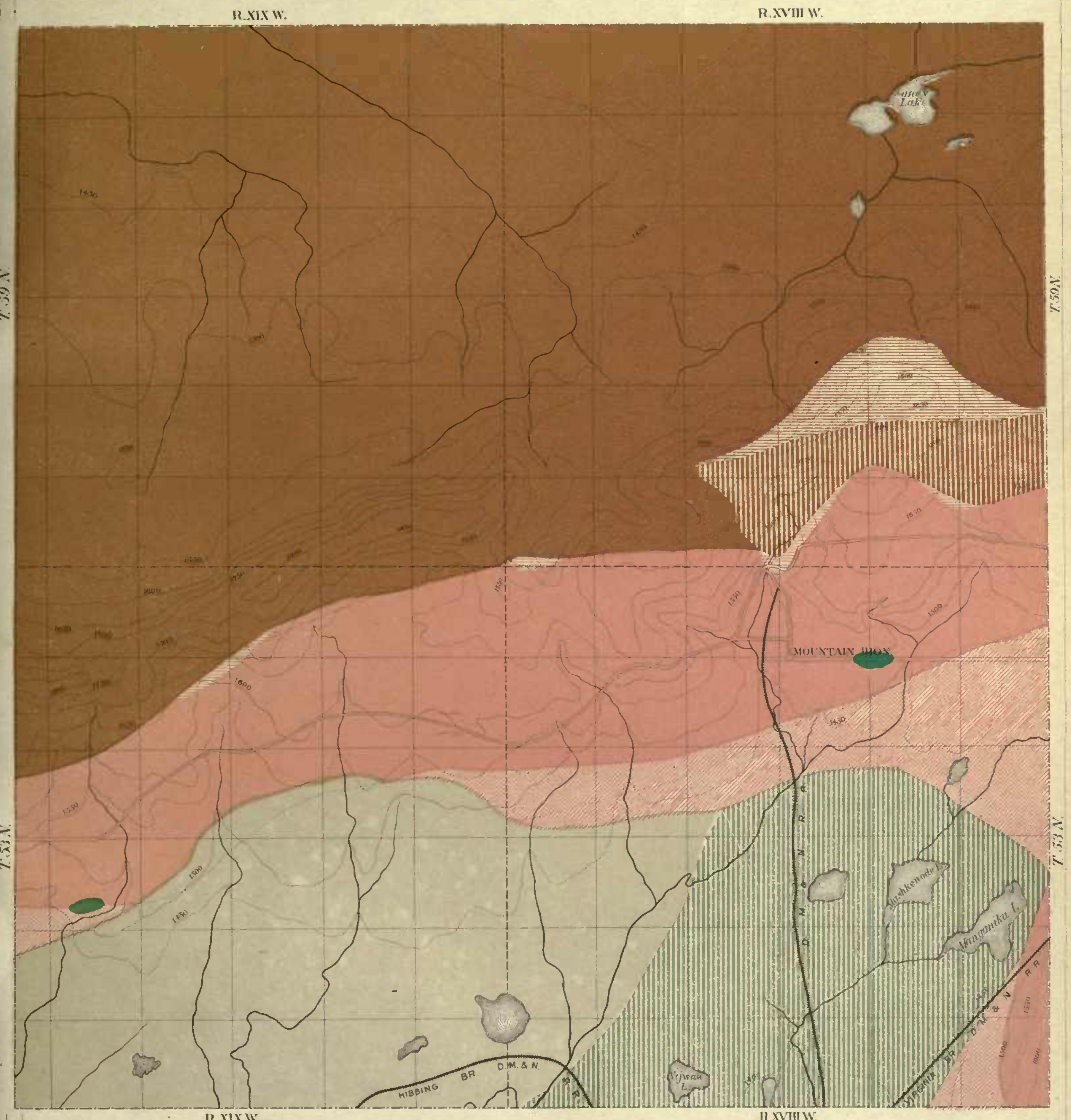
PLATE LXXIV.

THE MOUNTAIN IRON PLATE OF THE MESABI IRON RANGE, 1899. N. H. WINCHELL.

The granitic area, in this plate, has not been thoroughly examined. The topography here is that of an Archean granite and gneiss somewhat modified by a thin spreading of drift. But along the rough tract known distinctively as the Giant's range the drift is more abundant and frequent boulders are on the surface. South of the granite, while the elevation is less, the boulders are perhaps more common, one of the most notable kinds being a fine-grained, white quartzyte which, at a distance, appears like marble. These are from a quartzyte that accompanies, and usually underlies, the taconyte, but quite different from the quartzyte that causes the falls of Pokegama which, as already stated, is probably later than the age of the Mesabi ore. South from the ore-bearing rocks the surface slopes gently to the flat land and finally to the swampy tract which is included in the area of glacial lake Upham.

The first discovery of valuable iron ore on the Mesabi range was made at the Mountain Iron mine. It was by Capt. J. A. Nichols, in November, 1890. A shaft was sunk through fifteen feet of drift materials and entered a rich, soft hematite. This was but a short distance south from an outcrop or nearly vertical bluff of jaspery ore which had invited the attention of several explorers, but which had not rewarded them with satisfactory results. This bluff is near the granite and probably lies on the granite, or, at least, on the Archean. In the light of later interpretations of the features of the Mesabi ore, this bluff is supposed to represent a rhyolitic lava, silicified, lying near the old beach of the Animikie ocean, and from it was derived a large amount of basic obsidian sand, which was carried into the ocean and distributed in shallow water near by. The old, glassy rhyolyte, and the sand which it produced under the action of the beach line, have both been converted to siliceous and ferruginous rock, one making a jaspilyte and the other granular taconyte, the latter at this place varying to a rich pisolitic hematite.

The ore-bearing rock is several hundred feet in thickness. The ore is not uniformly disseminated through it, but occurs in large, irregular lenses, dependent on not only the existence of the original beds of greensand, *i. e.*, obsidian sand, but also on the ease with which water could enter them and carry on the progressive chemical alteration which has resulted in iron oxide and silica. Such alteration has produced a shrinkage in the bulk of the strata, at least when the change is wholly to oxide of iron, and the strata, at the present time, show a prevailing dip toward the centre of such ore lenses.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

MOUNTAIN IRON PLATE

BY N. H. WINCHELL.

Explanation

Modified drift
Glacial drift. Till
Cretaceous
Taconic { Black slate, Taconyte, Qurtzyte } Animikie
Archean { Granite, Post Keewatin; Keewatin; Mica schists }
Railroads
Wagonroads
Fifty foot contours
Hundred foot contours

Contour Lines are shown approximately for every 50 feet above the sea.

The Cretaceous ocean was once spread continuously over this part of the Mesabi range, and hence probably over much of northeastern Minnesota. Cretaceous strata are known at several points within the area of this plate, and they may exist extensively in the swampy tract lying south from the Mesabi range drained by the St. Louis river and its tributaries. N. H. W.

PLATE LXXV.

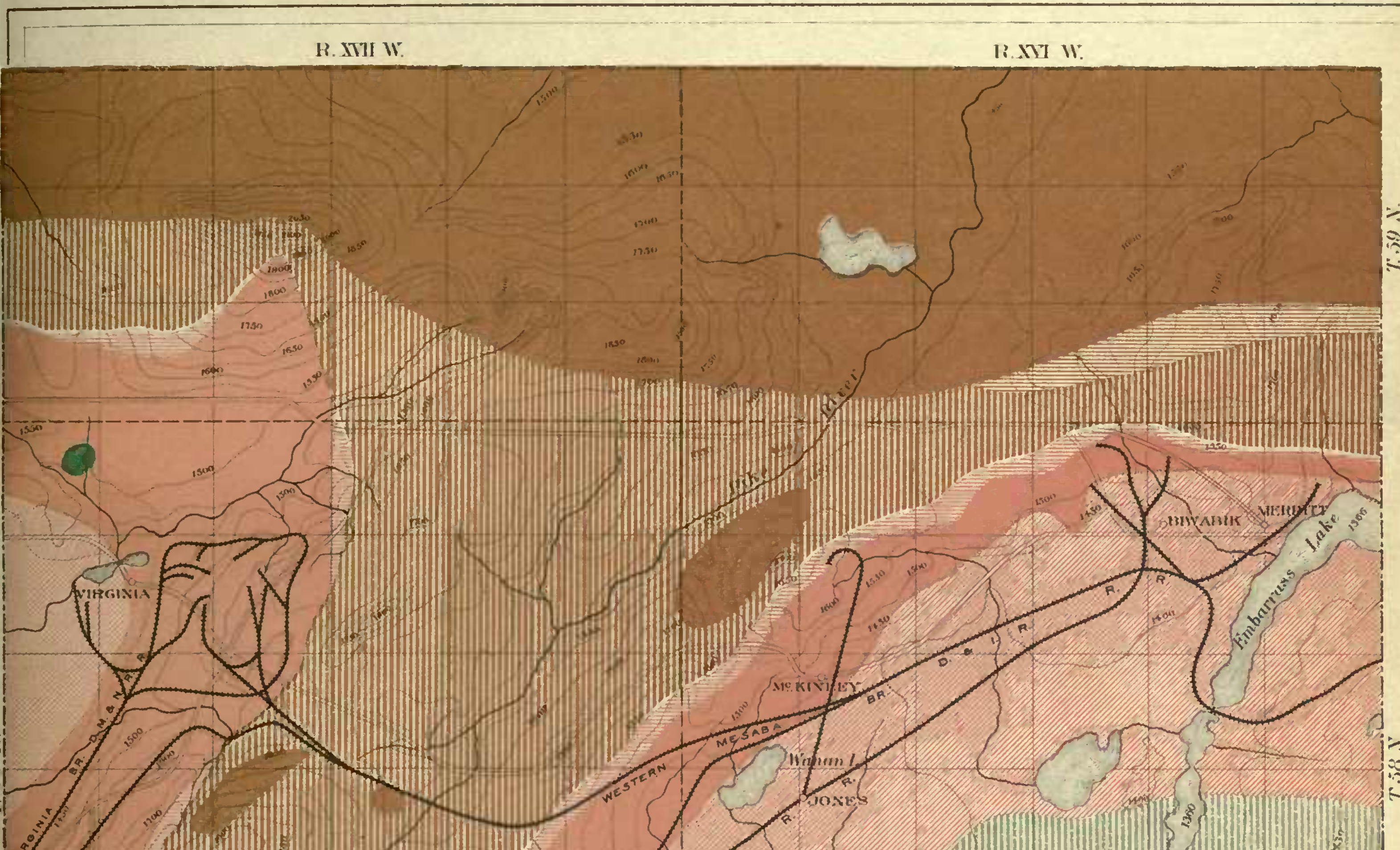
VIRGINIA PLATE OF THE MESABI IRON RANGE, 1899. N. H. WINCHELL.

Within the area of this plate are some of the principal mining centres of the state, viz., at Virginia, Eveleth and Biwabik. The rocks of the Animikie here swing out from their normal strike, toward the south about seven miles, forming a loop about a spur of the Archean. They dip in all directions from this Archean spur, and also are thrust northward onto the Archean area, at the western base of the spur, the taconyte horizon running beyond the limit of the quartzyte. According to Mr. Spurr there are several instances of irregularity in the normal superposition and geographic location of the parts of the Animikie. These are not all represented on this plate (see Bulletin x). These abnormal conditions—abnormal for a wholly sedimentary rock—are entirely consistent with the normal action of volcanoes or other igneous ejections such as are necessary if the taconitic greensand was due to an original volcanic source.

The Archean granite rises in isolated knobs at three spots in the Archean spur which, as a whole, is composed of characteristic Keewatin. The conglomeratic composition seen at the railroad cuts in secs. 15 and 22, T. 58–17, within a mile east of Mariska, indicates that the base of the Upper Keewatin is here seen. Between the Keewatin and the granite at the northeast corner of the plate a narrow belt of crystalline schists runs three or four miles.

The black slates are well known in this area. Their lowest strata are somewhat calcareous, and in places they become flinty. When they are flinty, and are near the taconyte, the iron frequently takes the form of siderite.

The Cretaceous has been found in the area of this plate and has furnished fossils of Ostrea, Inoceramus, Modiola, Pinna, Yoldia(?), Trigonarca Actæon, Trochus and Fasciolaria. The "gravel ore" found at the Lone Jack mine is probably a coarser portion of the Cretaceous near its base. N. H. W.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

VIRGINIA PLATE

BY N. H. WINCHELL.

Contour Lines *are shown approximately for every 50 feet above the sea.*
Figures in Lakes denote altitude above the sea.

Explanation

Modified drift
Glacial drift, Till
Cretaceous
Taconic { *Black slates* / *Taconyte* / *Quartzyte* } *Animikie*

Archean { *Granite Post Keewatin* / *Keewatin.* / *Mica schist* }
Railroads
Wagonroads
Fifty foot contours
Hundred foot contours

PLATE LXXVI.

PARTRIDGE RIVER PLATE OF THE MESABI IRON RANGE, 1899. N. H. WINCHELL.

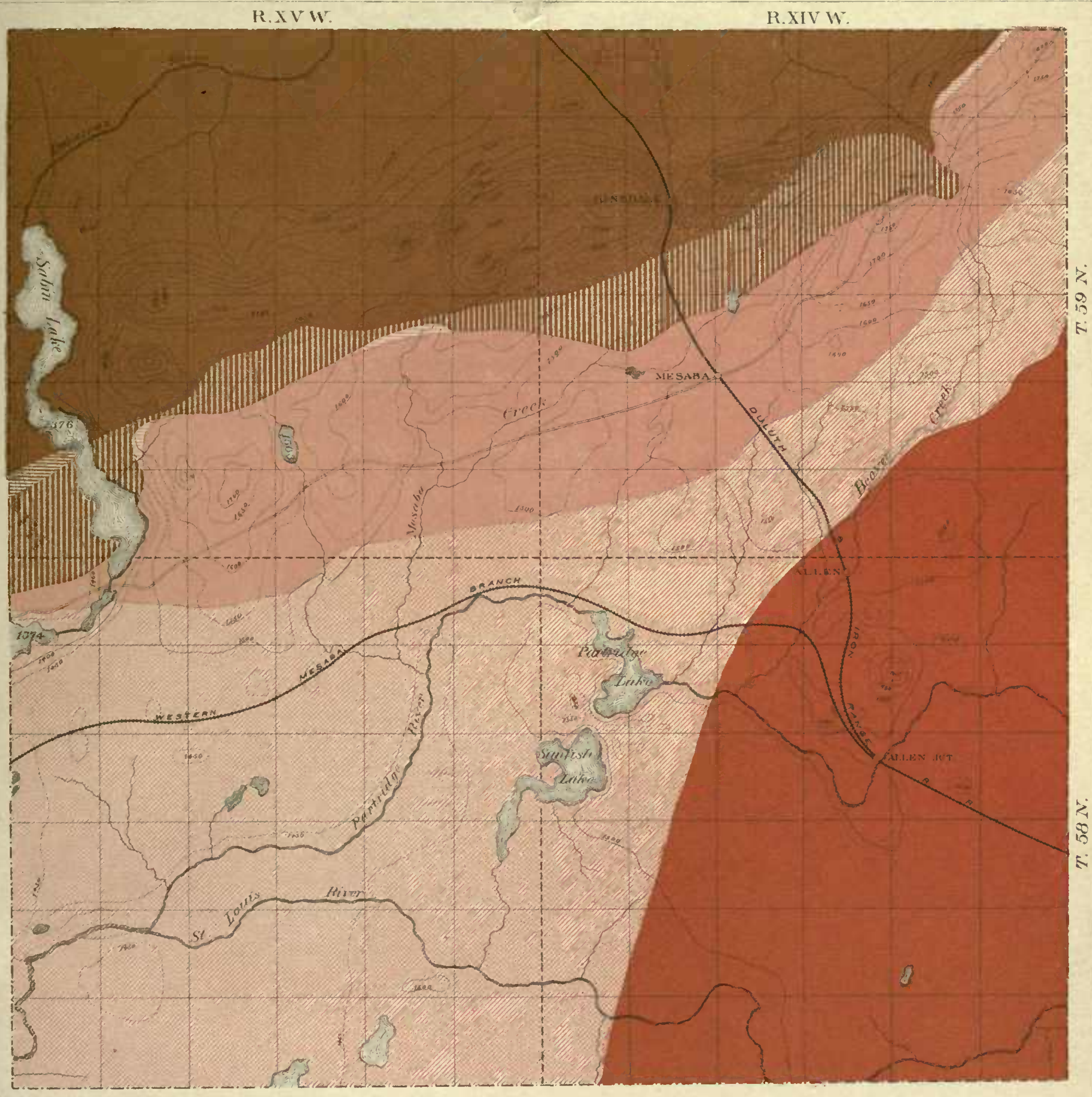
The Keewatin is nonconformably overlain by the Animikie along the southern slope of the Giant's range. The only known place in Minnesota where, under such relations, both formations are iron bearing is in sec. 11, T. 59–14. This repeats the structural relations so common in the Marquette district of Michigan. The iron ore of the Keewatin is jaspilitic rather than taconitic. Other rock of the Keewatin in the immediate vicinity is not ore, but greenish gray, fine grained, and embraces crystals of striated feldspar, evidently one of the fragmentals seen largely in the Keewatin in other places. The jaspilitic ore varies to a quartzyte of fine grain. Indeed, the most of the ridge exposed near the centre of section 11, as mentioned, is composed of nearly pure "chalcedonic" quartz, the structure being nearly vertical. The excavation formerly known as the Mallmann mine, a little northeast of this jaspilyte ridge, is in Animikie strata, dipping southeastwardly.

The quartzyte and taconyte at the bottom of the Animikie seem not to have uniform and independent stratigraphic positions, but in some cases they are found to alternate or to be wanting, one or the other. Besides, it is apparent that a large part of the quartzyte is not of detrital origin, but more probably of the nature of a chemical precipitate, or of chemical and detrital nature combined. When subjected to metamorphism such a rock becomes finely crystalline gneiss.

That exploration for ore in N. W. ¼ sec. 18, T. 59–14, supposed to be in the Animikie, is probably wholly within the Keewatin, and the granular fine structure of the ore is not due to a taconitic original structure, but to a fragmental jaspilyte such as that seen in the conglomerate of the "south ridge" at Tower, the horizon being at or near the bottom of the Upper Keewatin. This is the most likely explanation, based on a re-examination of the hand samples collected by Mr. Meeds.

The black slates are rendered crystalline, and converted to a cordierite mica schist. They appear thus in N. E. ¼ S. W. ¼ sec. 9, T. 58–14, along the shores of Partridge river.

The gabbro is exposed in the vicinity of Allen and Allen Junction. It rises in low, massive, gray domes, but in some places it appears to be undergoing a bouldery disintegration, which is due to some original variation in the grain and texture of the rock itself. This original difference in the grain and texture of the gabbro is to be ascribed to a coarsely fragmental or pebbly or agglomeratic composition of the greenstone of the Keewatin, from which the gabbro has been generated by intense metamorphism, but little short of fusion. N. H. W.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

PARTRIDGE RIVER PLATE

BY N.H.WINCHELL,

Contour Lines *are shown approximately for every 50 feet above the sea.*
Figures in Lakes denote altitude above the sea.

Explanation

Cabotian { *Gabbro*

Animikie { *Black slates*, *Taconyte*, *Quartzyte*

Archean { *Keewatin*, *Granitic*, *Mica schist*

Railroads
Wagonroads
Trails
Fifty foot contours
Hundred foot contours

PLATE LXXVII.

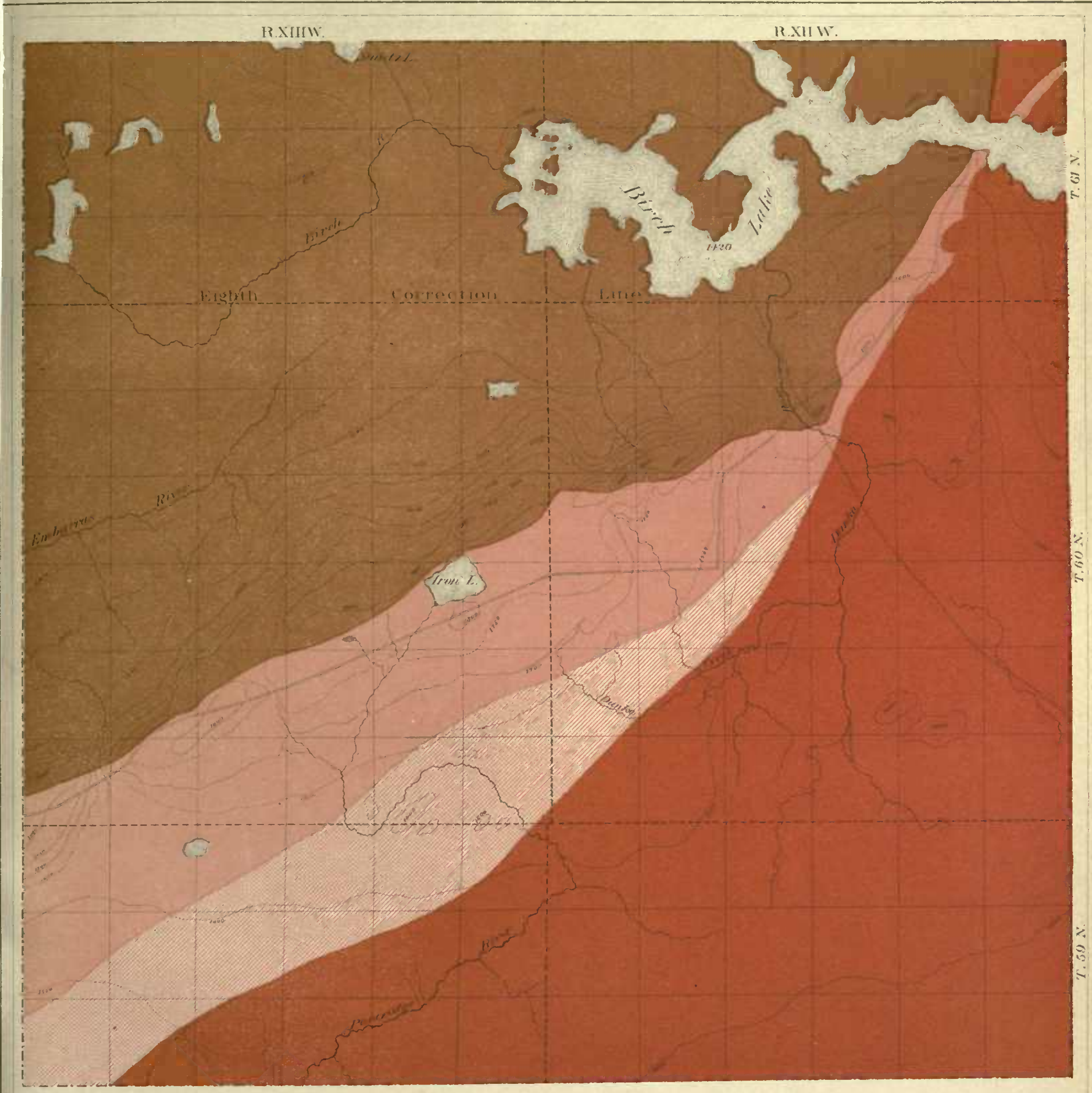
Dunka River Plate of the Mesabi Iron Range, 1899. N. H. Winchell.

The northwestern half of this area is occupied by the Archean, consisting of a light-colored granite, which varies, however, at the northwest end of Birch lake to a darker rock which is dioritic. This Archean also includes some gneiss, especially along the northern side of Birch lake, and some mica schist, the last appearing like a breccia cemented by granite. The granite sometimes is coarsely crystalline, with porphyritic Carlsbaded orthoclases.

The iron ore horizon presents some interesting variations. The horizon of the quartzyte, with respect to the taconyte, is not constantly the same, but the two are sometimes interbedded. This interbedded quartzyte is finely fragmental, and its grains have been enlarged by secondary silica. In this quartzyte are also grains of feldspar, actinolite, iron ore and epidote, but these are rare, feldspar being the most frequent of these accessories. There is a more coarse and granular quartzyte which verges to a conglomerate whose nature depends on the adjacent Archean. This forms the bottom of the Animikie. The coarser part of this conglomeratic quartzyte is rather thin, and when the fine-grained portion (above) is well developed the coarser quartzyte appears to be not more than twenty feet. This fine-grained quartzyte is more in evidence along the Mesabi range westward, in form of boulders, than the coarser part near the base. These boulders are quite numerous between Mountain Iron and McKinley, and, when weathered, at a distance they appear to be limestone masses. Not only does the coarser quartzyte appear sparsely in scattered, rounded grains in the bottom of the finer, but the fine cementing silica of the finer rock is found to pass downward into the coarser rock, making secondary deposition of quartz on the clastic grains.

Observations made within the area of this plate seem to demonstrate the separateness of the Animikie from the Upper Keewatin and the ferruginous taconitic nature of the base of the Animikie where it lies on the Archean, whether on the granite or on the Keewatin.

The gabbro, in its northern margin, goes diagonally across this area, and comes into contact, from southwest to northeast, successively with the different parts of the Animikie and then with different parts of the Archean. In the region south of Birch lake, in the north part of T. 60–12, and on the north side of Birch lake, there is much doubt about the age of the iron-bearing rock. The composition and structure of the ore, as well as the nature of the associated minerals, are different from the same further west. There is reason to believe that the ore associated with olivine



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

DUNKA RIVER PLATE

BY N.H. WINCHELL.

Contour Lines *are shown approximately for every 50 feet above the sea.*
Figures in Lakes denote altitude above the sea.

Explanation

Cabotian	*Gabbro*
Animikie	*Black slates*
	Taconyte and quartzyte
Archean	*Granite*
	Wagonroads
	Trails
	Fifty foot contours
	Hundred foot contours

and pyroxene in the valley of Birch lake belongs to the Keewatin rather than the Animikie, and is a metamorphic phase of ore lodes peculiar to the Lower Keewatin, due to the gabbro revolution. The peculiar lithology of these Keewatin ore bodies is discussed in volume v. The ferromagnesian minerals in the ore were probably derived from basic debris which was originally associated with the sedimentary jaspilyte. These increase in amount and in variety, the iron and the quartz diminishing until the rock changes to muscovadyte, and thence into gabbro. N. H. W.

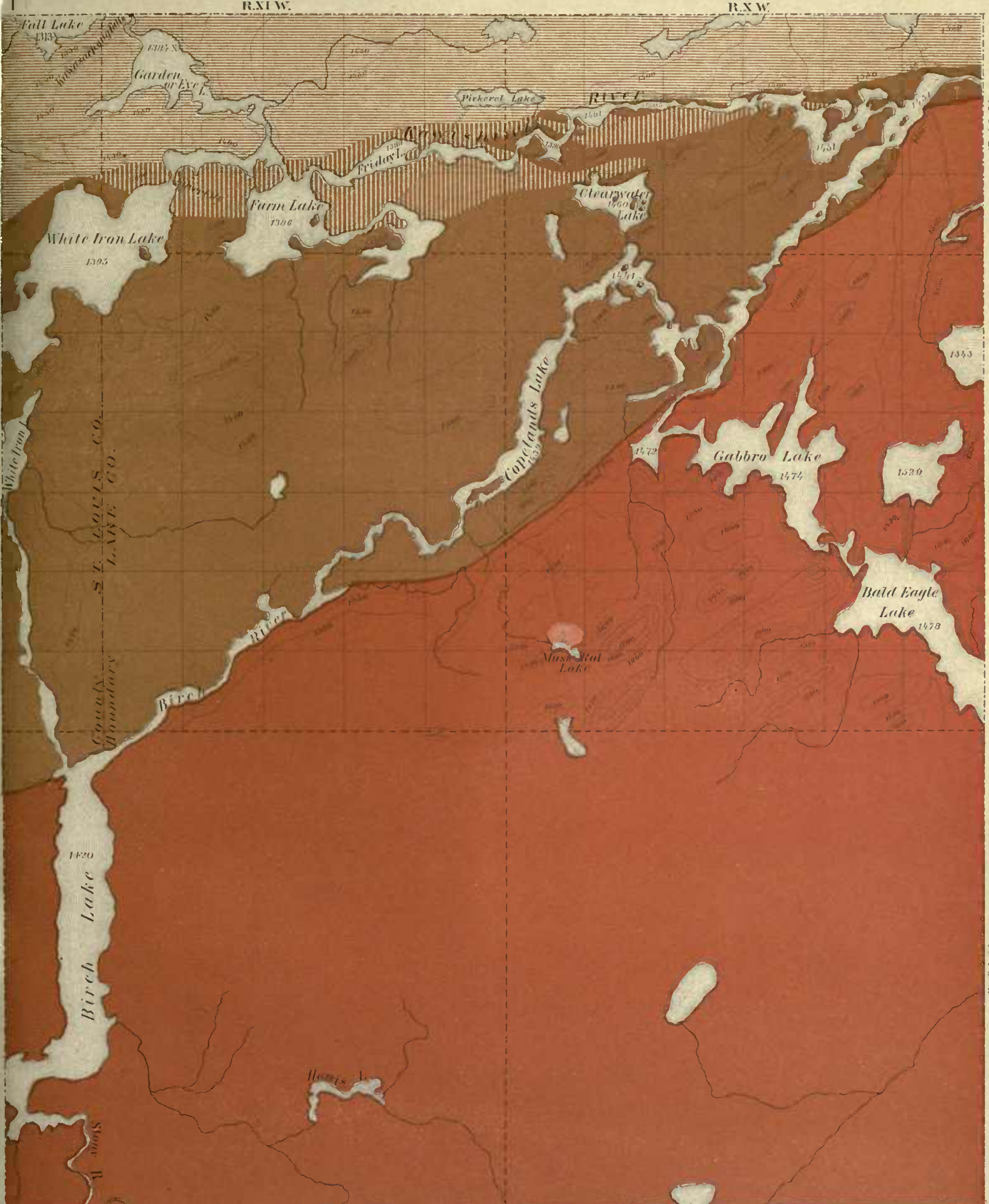
PLATE LXXVIII.

THE GABBRO LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

In the area of this plate are important and interesting exposures of the Archean, including greenstone, with jaspilyte, mica schist, dioryte and intrusive granite and syenyte.

The field notes and descriptions made by the writer (1886), quoted by Dr. Grant in the text of volume iv, represent the greenstone as mainly igneous about Fall lake and Garden lake, but later investigation of the rock samples collected has shown that, so far as known, the greenstone of that region is all, or nearly all, of clastic origin. The succession of parts described at Garden lake, illustrated by rocks Nos. 1017 to 1023, was responsible for the inference by the writer that the schist graduated into a massive crystalline rock, *i. e.*, from No. 1017 to 1023. The inference is correct so far as concerns the graduation, but the rock No. 1022, from which the schist was supposed to have been derived, is not a massive crystalline. It is simply a more coarse one than the schist, and both are clastic, sheared, basic, consolidated Keewatin sediments, the gradation being one of varying sedimentation. This early error was corrected when the rock samples were finally examined (volume v, p. 633).

It is in rock of this kind, but usually more plainly of fragmental origin and even of sedimentary structure, that occur the jaspilyte ore bodies of the Vermilion range. Generally the main structure and direction of trend of the ore bodies agree with the same of the greenstone, and there is sometimes a sedimentary alternation of jaspilitic rock with green schist, showing a subordination of the jaspilitic rock to sedimentary forces. But besides this structure, which is sometimes only a marginal feature of the ore lenses, though it sometimes characterizes the whole mass, the jaspilyte manifests a different, much curling, structure, which runs in defiance of the general direction and turns upon and within itself. Such curling jaspilyte has never been seen to contain bands of sedimentary green schist, or other fragmental materials, and seems not amenable to the sedimentary theory. It is interpreted by the hypothesis that originally this rock was a basic obsidian, erupted in submarine conditions, and, being in a noncrystalline condition, was silicified by the deposition of silica from the oceanic waters, the silica preserving, as in fossil wood, the structures of the original. Cotemporary with this silicification of the igneous mass other chemically precipitated silica was arranged conformably in a sedimentary banding and sometimes in alternation, or closely mingled with all the products of detrital action that could be furnished by the physical environment. Thus are produced two forms



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

GABBRO LAKE PLATE

COMPILED BY U.S.GRANT.

Explanation

Wagonroads
Trails
Fifty foot contours
Hundred foot contours

Cabotian { *Gabbro*
Animikie { *Taconyte or iron bearing member*
Archean { *Keewatin. Quartz-magnetite and mica schists*; *Keewatin. Largely greenstones and jaspilyte.*; *Granite and syenite*

Contour Lines *are shown approximately for every 50 feet above the sea.*

Figures in lakes denote altitude above the sea; when followed by X the figures were obtained by leveling

of primary jaspilyte, one igneous and one sedimentary. These belong in the Lower Keewatin, as a rule; but in the basal conglomerate of the Upper Keewatin is found a secondary or fragmental jaspilyte, consisting of detritus from the original jaspilyte of the Lower Keewatin. This is common on the "south ridge" at Tower. It is sometimes very coarse, but also grades into grit and graywacke. N. H. W.

PLATE LXXIX.

SNOWBANK LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

It is within the area of this plate that can be seen some of the most interesting relations existing between the clastic and the massive rocks. The Archean exhibits here nearly all the original rocks, whether massive or fragmental. The Upper Keewatin occupies the larger part of the Keewatin area. It is usually plainly conglomeratic and often bedded. The older Keewatin is probably that which occupies a belt running southwestwardly across the northwest corner of the plate.

The Upper Keewatin becomes crystalline. It makes mica schists and gneisses, as can be seen plainly about the shores of the northern and western parts of Snowbank lake. It also forms a granitic rock in which the forms of boulders are more or less preserved; as the transformation proceeds the crystalline product loses all outward trace of clastic origin and its megascopic appearance and intrusive action on the adjoining mica schist reveal it as an igneous rock. It is then only by microscopic examination that the old fragmental structure can be seen. The various original grains, say of feldspar, are divided between fresh growths and remnants of decayed feldspar grains. The decay products are clustered together, usually at or near the centres of the feldspars, and they are themselves crystallized into new silicates, largely muscovite, chlorite and epidote.

The southern arm of the syncline of the Lower Keewatin is involved in the gabbro, and the gabbro also embraces the more basic southern part of the Upper Keewatin. The relation of the gabbro to the Keewatin greenstone can be studied at the iron location at the south shore of Disappointment lake, and northeastwardly along the border of the gabbro. The basic rock of the Keewatin becomes crystallized with the formation of numerous new minerals, such as characterize basic igneous rocks, viz., hypersthene, magnetite, diallage, augite, labradorite, olivine. There is a stage of the transformation from greenstone to gabbro corresponding to the mica schist or gneissic stage that precedes the production of granite. It has been named muscovadyte, but it varies in composition according to the nature of the original basic rock. In one of its conditions it is noryte, and it is sometimes plainly allied to the greenstone, and can be traced directly into it, and sometimes it is plainly a phase of gabbro. There are almost infinitely varied shades of structure and composition in the rock muscovadyte, but they all lie between basic Keewatin greenstone, sometimes conglomeratic, and coarse gabbro that originated from the greenstone in early Keweenawan time. The great hill of Upper Keewatin conglomerate which is on the east side of sec. 34, T. 64-8, a very conspicuous object from nearly

R. IX W.

R. VIII W.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

SNOWBANK LAKE PLATE

COMPILED BY U.S.GRANT.

Contour Lines are shown approximately for every 50 feet above the sea. Figures in Lakes denote altitude above the sea; when followed by X the figures were obtained by leveling.

Explanation

Cabotian	Gabbro
Animikie	Taconyte or iron-bearing member
Archean	Granite
	Conglomerates, mica schists
	Argillytes, graywackes, jaspilyte
	Quartz porphyry
	Greenstones with jaspilyte
	Mica and hornblendic schists.

Trails — Fifty foot contours — Hundred foot contours

all directions, illustrates one of the stages of transition from conglomeratic greenstone to the gabbro. The fine clastic material is compacted and crystallized into a rock which, in the field, appears like diabase, and in the field it was styled diabase. In thin section (No. 499H) it shows, first of all, a large number of small uralitic hornblendes. These lie in a finer matrix consisting of a confused mixture largely of feldspar, but in which are fine particles that appear to be magnetite. The rock is evidently the product of imperfect metamorphism of a fine basic debris.

The iron ore south of Disappointment lake is structurally a part of the muscovadyte stage of the greenstone-gabbro transition, but whether a part of the Upper or Lower Keewatin is uncertain. N. H. W.

PLATE LXXX.

THE FRASER LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

This area rivals that of the Snowbank Lake plate in interesting geological problems. On both much work has been bestowed, both in the field and in the laboratory. These problems are discussed in their order in volumes iv and v.

The most indubitable proof of the origin of the granite of Kekequabic lake from clastic Upper Keewatin strata can be seen about the southern shores of that lake. This is the product of intense metamorphism of comparatively acid rock. As the original rock passes to less and less acid character the resulting massive rock has a different composition. It can hardly be styled granite because of the presence of some of the minerals of gabbro, nor yet gabbro because of the presence of so many granitic elements. In this transition interval are the rocks muscovadyte, with its variations, "contact rocks," porphyrel, conglomeratic granite, mica schist and noryte, some being due to variations in the original clastic and some to different degrees of metamorphism.

It has been assumed that the granitic metamorphism represented by this plate was earlier than that due to the Cabotian disturbance of the Keweenawan, but that is not proven. It may be found that this and the Snowbank Lake granite are of the same date as the gabbro.

The iron ore that is seen on the north shore of Fraser lake and on the south side of Gabemichigama lake, pertain to the gabbro-greenstone zone of transition. They are in the midst of more or less siliceous muscovadyte or quartzyte, and are supposed to be derived from original jaspilyte lodes that existed in the Lower Keewatin prior to the gabbro revolution. N. H. W.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

FRASER LAKE PLATE

BY U.S.GRANT.

Trails
Fifty foot contours
Hundred foot contours

Explanation

Diabase dikes
Cabotian { Gabbro
Animikie { Taconyte or iron-bearing member
Keewatin ? Gabbro contact rocks.
Archean { Keewatin, Argillytes, graywackes, tuffs, conglomerates, greenstones, etc.
Augite soda granite

Contour Lines are shown approximately for every 50 feet above the sea. Figures in Lakes denote altitude in feet above the sea, when followed by X the figures were obtained by leveling

PLATE LXXXI.

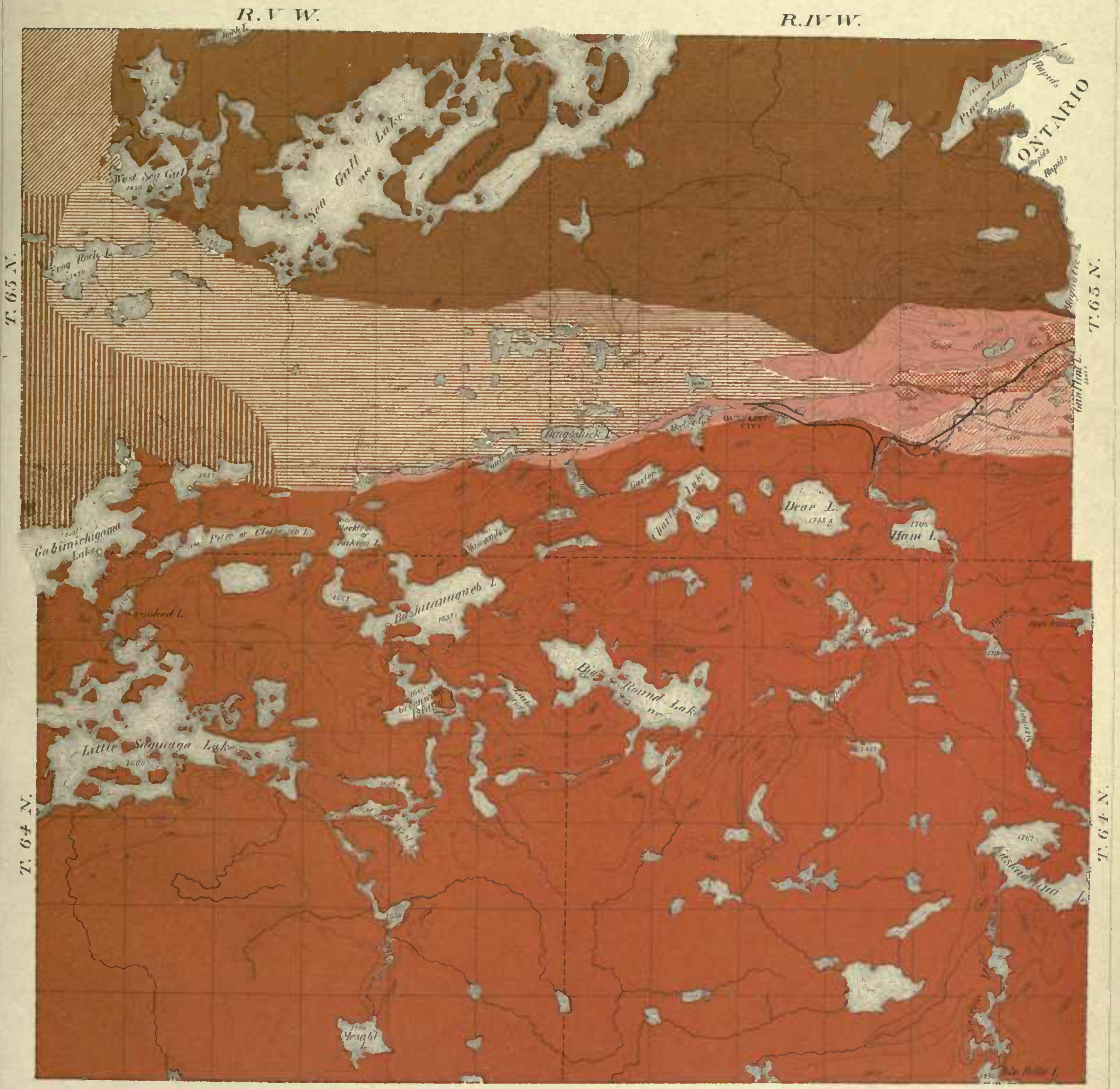
AKELEY LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

It will be seen from the report of Dr. Grant on this plate that there are different opinions as to the age and nature of the iron-bearing rocks of this area, and that this difference extends to the muscovadyte phase of the gabbro.

The writer's views of the iron-bearing rocks of this area are expressed on the "map of the Mesabi Iron range," inserted at the close of volume iv. The Keewatin iron belt, which is mentioned near the centre of sec. 11, T. 59-14, in connection with the Partridge River plate (vol. iv. p. 385) as distinct from the Animikie, seems to continue, in connection with the gabbro in which it becomes involved, interruptedly across the Dunka River plate area, where its chief known outcrops are east of the Dunka rivêr and north of Birch lake, across the Gabbro Lake plate, where it is known at but one point (at Muskrat lake), and to Disappointment lake, on the Snowbank Lake plate, where it shows unmistakably its alliance both with the jaspilyte and the greenstone of the Keewatin, as it is located outside of the gabbro and conformably in the strata of the muscovadyte stage of the greenstone. Thence northeastward it is again encroached on and lost in the gabbro, appearing on the Fraser Lake plate at but three places, so far as known. But on the Akeley Lake plate it is represented by a long, narrow series extending nearly across the plate and apparently running, with the greenstone, beneath the Animikie.

As in Michigan, these two ore horizons, where they exist in close proximity, have sometimes been confounded in one. In Michigan they were for many years all referred to the horizon of the Vermilion ores, and that was originally done for Minnesota by the officers of the United States Geological survey. It required considerable research and frequent presentation of the varied facts to convince some geologists that the Animikie ores were in a different horizon from those of the Vermilion range; but owing to the simplicity of the grand structure of northeastern Minnesota, on which the distinction was firmly based in the early years of the Minnesota survey, the two ore horizons have been recognized by all geologists.

Now the pendulum has swung into the opposite end of the arc, and in its initial movement in that direction the Minnesota survey admits the responsibility for the error. These ores, through the gabbro area, and at Disappointment lake, were, at first, before any adequate study had been given to their structural relations, and before their petrology had been examined into, mapped with the Animikie, thus making a continuous belt of Animikie ore from Gunflint lake to the Mississippi river. Some ores were thus hypothetically transferred from the lower horizon to the upper;



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

AKELEY LAKE PLATE

BY U. S. GRANT

Contour Lines *are shown approximately for every 50 feet above the sea.*
Figures in Lakes denote altitude above the sea;
when followed by X the figures were obtained by leveling

Explanation

- Cabotian
  - *Gabbro*
  - *Diabase sills*
- Animikie
  - *Black slate member*
  - *Taconyte or iron-bearing member*
- Archean
  - *Upper Keewatin, Conglomerates, slates, graywackes, etc*
  - *Unclassified Keewatin, schists, slates, graywackes, etc*
  - *Greenstones.*
  - *Granite*
- *Railroads*
- *Wagonroads*
- *Trails*
- *Fifty foot contours*
- *Hundred foot contours*

and it is equally difficult to correct this error as it was the former one, *i. e.*, it is equally as difficult to convince some geologists that they should not all go together into the Animikie.

Besides the points of difference mentioned by the writer at various places in volumes iv and v (vol. iv, pp. 398, 546; vol. v, pp. 69, 990–999) between the ores and the containing rocks of the Vermilion and Mesabi ranges, the following further distinctions should be noted between the recognized Animikie ores and those that are involved in the gabbro or its variation, the muscovadyte, in the areas of Plates LXXVII–LXXXI:

1. The Keewatin ores and rocks dip, in the Akeley Lake area, an average of 45°, and the Animikie an average of 10°, the former becoming almost vertical and the latter almost horizontal (vol. iv, p. 471).

2. The Keewatin ores are associated with muscovadyte, which is a metamorphic state of Keewatin sediments, but nothing of the kind is found in the Animikie, but only diabase constitutes those sills. Such diabase, when the sills are very thick, acquires gabbro characters, but never muscovadyte characters. The narrowest sill in the Animikie is diabasic; the narrowest in the Keewatin jaspilyte, when thus metamorphosed, is still muscovadyte.

3. The muscovadyte characters, both in size of grain and in composition, fade out into the enclosing quartzose magnetite layers like an original sedimentary transition, several of the minerals from one side or the other trespassing across the general boundary, but in the case of the sills of the Animikie the transition, observed under the microscope, is distinct and abrupt from igneous rock to clastic.

4. The ends of the anticline, hypothecated by Dr. Grant (vol. iv, p. 474), have very different lithology, although they both lie on the greenstone, and if both are Animikie they should be almost identical. Compare rocks Nos. 1896 and 879G with No. 1895, described in volume v. One is no more crystalline than the other, but having a different aggregate composition is composed of different minerals and in different proportions.

Again, these ores are not always contrasted by the titanium content, although the original Keewatin ores are nearly or quite free from titanium. The titanium per cent, apparently, depends on the thoroughness of the metamorphism, and is greatest when the rock was fused. Still, this general difference is remarkable and at present inexplicable. N. H. W.

PLATE LXXXII.

GUNFLINT LAKE PLATE OF THE MESABI IRON RANGE, 1899. U. S. GRANT.

The iron-bearing Animikie, within the area of this plate, presents interesting variations. These are discussed fully in connection with the question of the origin of the iron ores of the Mesabi range in Part III of volume v. The first suggestion that the iron-bearing member of the Animikie was primarily an igneous rock, varying from rhyolyte or obsidian to volcanic obsidian sand, since silicified, was derived from specimens collected on the north side of the peninsula between Gunflint and North lakes. This suggestion led to the grouping in one general class of several rocks that had before been supposed to have little or no genetic affinity.

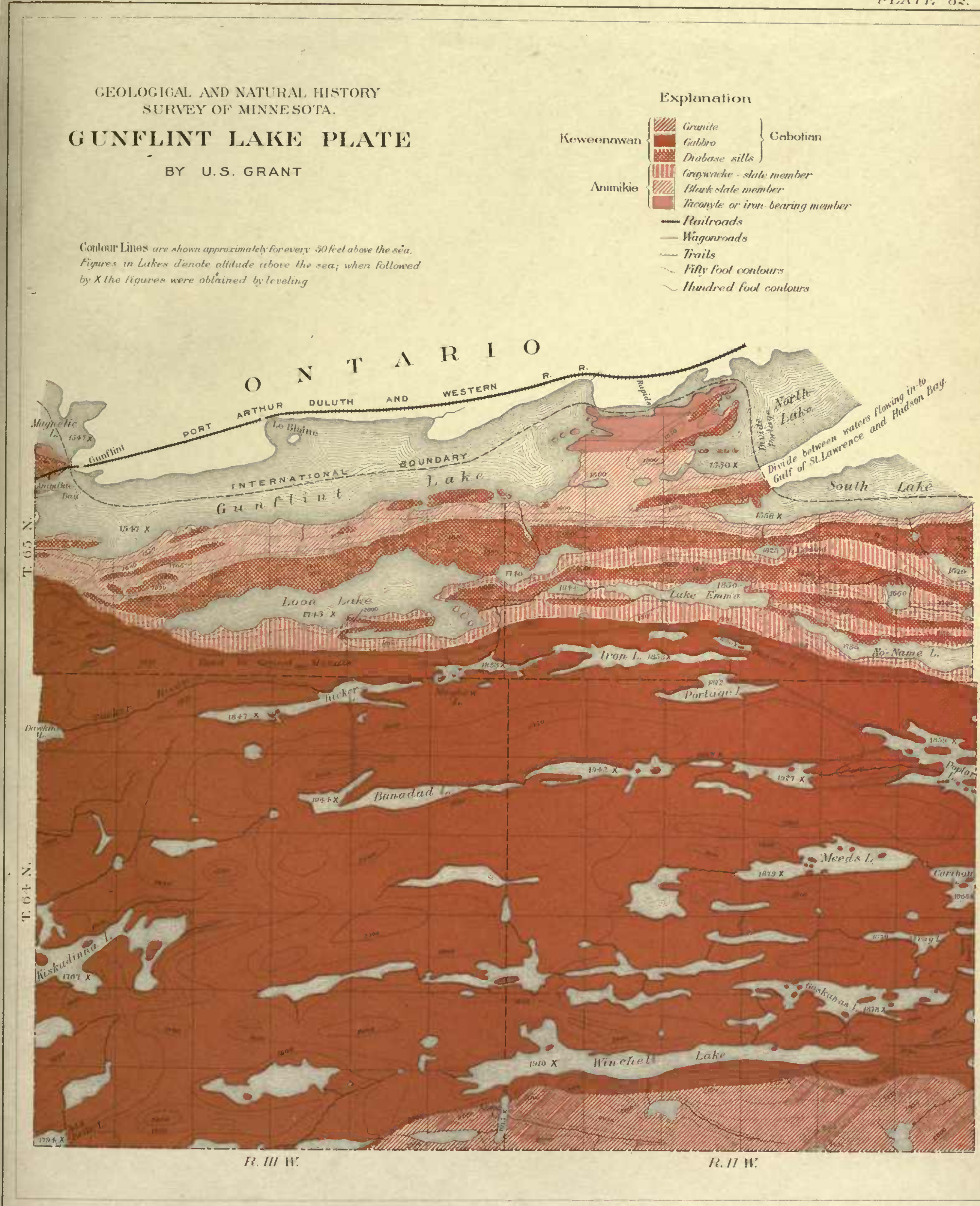
The earliest condition of the iron-bearing rock is seen at the westward from Gunflint lake, where it (apparently) lies on the granite of the Giant's range. It is in the isolated hill at the centre of sec. 24, T. 65-4. While the rock is considerably charged with magnetite and siderite it is also slaty and but little silicified. It is seen to embrace, near its upper surface, a singular breccia of flinty fragments, and here the iron-bearing rock which forms a cement or matrix for this breccia presents characters that show it was a surface lava. The flint fragments are apparently glassy parts (now silicified) of the lava first cooled but still embraced in the general flow (vol. v, p. 951).

This condition was followed and accompanied by a glassy rock (obsidian) in considerable amount. It forms breccias and conglomerates at the north of Gunflint lake, but in the true taconyte (which was originally a clastic obsidian sand) it causes the globular structure characteristic of that rock.

When this obsidian is not silicified it is greenish and isotropic, and was at first attributed to foraminiferal origin, and was called glauconite. It evidently formed sand beds of greater or less thickness distributed the whole length of the Mesabi range. The "soft" iron ore, which is the same as this obsidian sand, though converted to hematite, is sometimes 100 or 200 feet in thickness.

Associated with the obsidian sand was also rhyolyte, which possessed the streamed, contorted, banding characteristic of rhyolyte. This rhyolyte, as well as its fragmental debris, being usually amorphous, uncrystallized mineral matter, was subject to easy silicification. It has been hence converted to the banded jaspers (jaspilyte) which are occasionally seen associated with the taconyte of the Mesabi range but which are more abundant in the Vermilion range.

The silica which permeated these igneous rocks was derived in part from the ocean by chemical precipitation, the ocean probably being alkaline and perhaps, in the vicinity of igneous activity, also heated.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
GUNFLINT LAKE PLATE
BY U.S. GRANT
Explanation
Keweenawan
Granite
Gabbro
Diabase sills
Cabotian
Animikie
Graywacke - slate member
Black slate member
Taconyte or iron-bearing member
Railroads
Wagonroads
Trails
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.
Figures in Lakes denote altitude above the sea; when followed by X the figures were obtained by leveling
ONTARIO
PORT ARTHUR DULUTH AND WESTERN R. R.
INTERNATIONAL BOUNDARY
Gunflint Lake
North Lake
South Lake
Divide between waters flowing in to Gulf of St. Lawrence and Hudson Bay.
Loon Lake
Lake Emma
Iron L.
No-Name L.
Portage L.
Banadad L.
Meeds L.
Winchell Lake
Kiskadinna L.
Poplar L.
T. 65 N.
T. 64 N.
R. III W.
R. II W.

The iron was probably in the same manner precipitated, in part, from the ocean. Still, both silica and iron were doubtless supplied by the obsidian itself.

Whenever the cotemporary lava was not cooled rapidly, but became crystallized, it must have constituted, and probably constitutes to this day, igneous rock. If it was submarine it probably was affected by more or less impregnation by iron and silica. Such may be the cause of much of the aporhyolytes and so-called red rock, though perhaps not at this date. Yet it is not known what may be the date of the red granites, etc., of the Misquah hills which cross the southern part of this and the Akeley Lake plates.

The stratified flints of the region of Gunflint lake are probably derived from fine clastic, mostly igneous, sediments, mingled with chemical sediments, and are comparable to the sedimentary jaspilytes of the Vermilion Iron range (see the Vermilion Lake plate). They should not be confounded with the silicified apobsidian breccia mentioned above.

N. H. W.

PLATE LXXXIII.

THE ROVE LAKE PLATE, 1899. U. S. GRANT.

This area is divided in a pronounced manner between three types of topography. In the south is the rough country prevailingly occupied by the "red rock." Here are several hill ranges running nearly parallel with each other in an east and west direction, the principal one, in the southern part of T. 64-1 W., having the distinctive name of Misquah hills. This range contains the second highest known point in the state, viz., 2,223 feet above the sea, determined by surveyor's level. Another ridge is along the south side of Brulé river, containing Brulé mountain, on which is located lake Abita, the highest recorded lake in the state, 2,048 feet above the sea. A more southerly range runs along near the south limit of this plate, and is known, in T. 63-1 E., as Pine mountain. This ridge reaches an elevation, in the vicinity of Little Pine lake, of 2,000 feet.

The second type is underlain by the gabbro. It occupies a triangular area in the central part of the plate running to a point at the eastern margin. This is a comparatively smooth region, with much rock exposure and numerous lakes elongated east and west. This type is more marked in the area of the Gunflint Lake plate.

The third type of topography is caused by the peculiar manner of succession of the monoclines of the Animikie with their alternating sills of gabbro, or diabase. The ridges, running east and west, are usually capped by the igneous rock, which is sometimes 50 to 100 or 150 feet in thickness. Their lower parts are composed of slates and quartzytes belonging in the central and upper parts of the Animikie. The southern slopes of these ridges are gentle and descend frequently to lakes, below which the igneous rock continues. The northern slopes are precipitous and sometimes vertical, and descend across the faces of the sills which form the summits, and of the underlying slates of the Animikie. This type of topography is likewise characterized by east and west lakes, like that of the gabbro. There are some remarkable hills belonging in this area. They are near the international boundary.

The geological boundaries shown on this plate are not exact, but quite general. The extent, as well as the nature and structural relations, of the red rock, is unknown. This rock is known to be associated with diabases and surface lavas, as well as with massive basic rocks of deeper-seated origin, and it is quite possible that these belong, in part, to the Manitou epoch of the Keweenawan instead of the Cabotian, being thus a westward extension of those represented on Plate LXXXIV about Greenwood lake.

N. H. W.

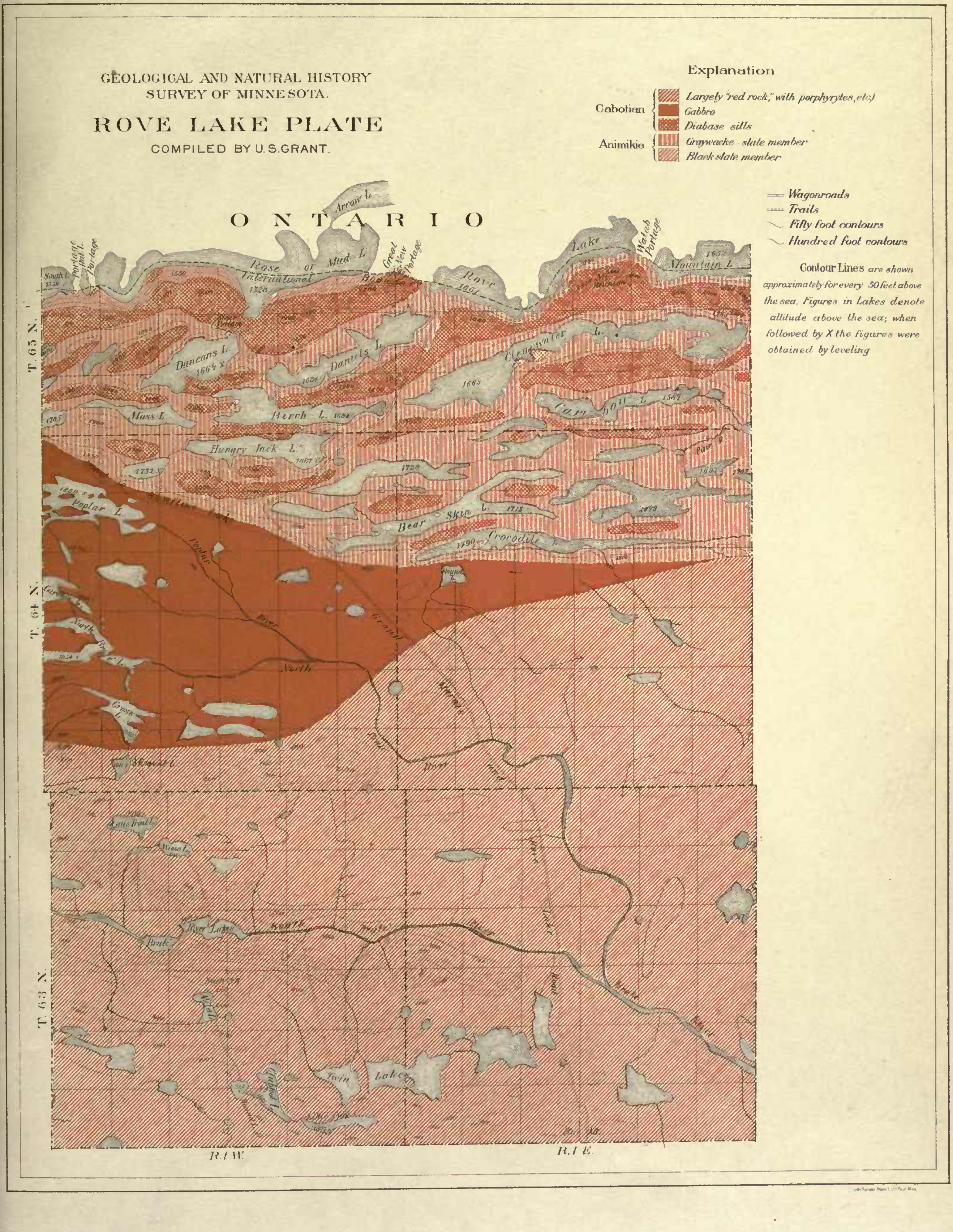

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
ROVE LAKE PLATE
COMPILED BY U.S.GRANT.
Explanation
Cabotian
Largely "red rock," with porphyrytes, etc.)
Gabbro
Diabase sills
Animikie
Graywacke - slate member
Black slate member
Wagonroads
Trails
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea. Figures in Lakes denote altitude above the sea; when followed by X the figures were obtained by leveling
ONTARIO
Arrow L.
Rose
Mud L.
Rove
Lake
Mountain L.
Duncans L.
Daniels L.
Clearwater L.
Moss L.
Birch L.
Hungry Jack L.
Poplar L.
Bear Skin L.
Crocodile L.
North
South
Twin Lakes
River Lakes
Brule
T. 65 N.
T. 64 N.
T. 63 N.
R. I W.
R. I E.

PLATE LXXXIV.

MOUNTAIN LAKE PLATE, 1899. U. S. GRANT.

On the international boundary a drift-covered tract begins about two miles south of South Fowl lake and extends to the eastern limit of this plate, and to the northwest end of the "Grand Portage" trail, on the next plate, being at least four miles wide. This drifted belt runs westward to the region of East Greenwood lake, and probably much further, but its direction and its features have not been ascertained, though it certainly passes south of the Misquah hills. Mr. Elftman has mapped it in a provisional manner as running southwestwardly to Devil's Track lake, north of Grand Marais,* forming a moraine of the Lake Superior ice-lobe, his Highland moraine. A part of this tract, on the international boundary, is flat and covered with lacustrine clay, making a very good agricultural area. It is certain, therefore, that the waters of the Pigeon river were dammed by the ice, forming a glacial lake. This has been named lake Omimi by Mr. Elftman.

The topography which is formed by the rocks proper undergoes a change in the area of this plate. The features of the Animikie province pass into Canada at the north side of this drift-covered belt, and the igneous rock that constitutes the sills in the Animikie proper appears in the form of dikes along the south of that belt. This feature only begins in this area, but is fully developed in the Pigeon Point plate area. These dikes are sometimes over a hundred feet wide, and rise boldly above the general surface, and do not have as much uniformity of direction as in the plates further west.

The rock which these dikes pass through is different from the Animikie that is characterized by sills of igneous rock. It is a kind of greenish graywacke, more fragile than the Animikie quartzytes and slates and not rigidly bedded, comprising much igneous matter. It has been named Grand Portage graywacke, from its geographic position. It has been supposed to be a part of the Animikie (the uppermost part), but it seems to run below not only the Puckwunge conglomerate but also the quartzytes and slates at Grand Portage village and of Pigeon point, which have been classed as Animikie, since the overlying conglomerate (the Puckwunge) seen in Grand Portage island contains their debris. As a formation this greenish-gray graywacke is not well known.

The Puckwunge conglomerate is taken to be the sedimentary base of the upper part of the Keweenawan. It is included in the Potsdam. The trap beds which overlie it are in the Manitou igneous epoch of the Keweenewan. N. H. W.

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*_American Geologist_, vol. xxi, plate XI. February, 1898.

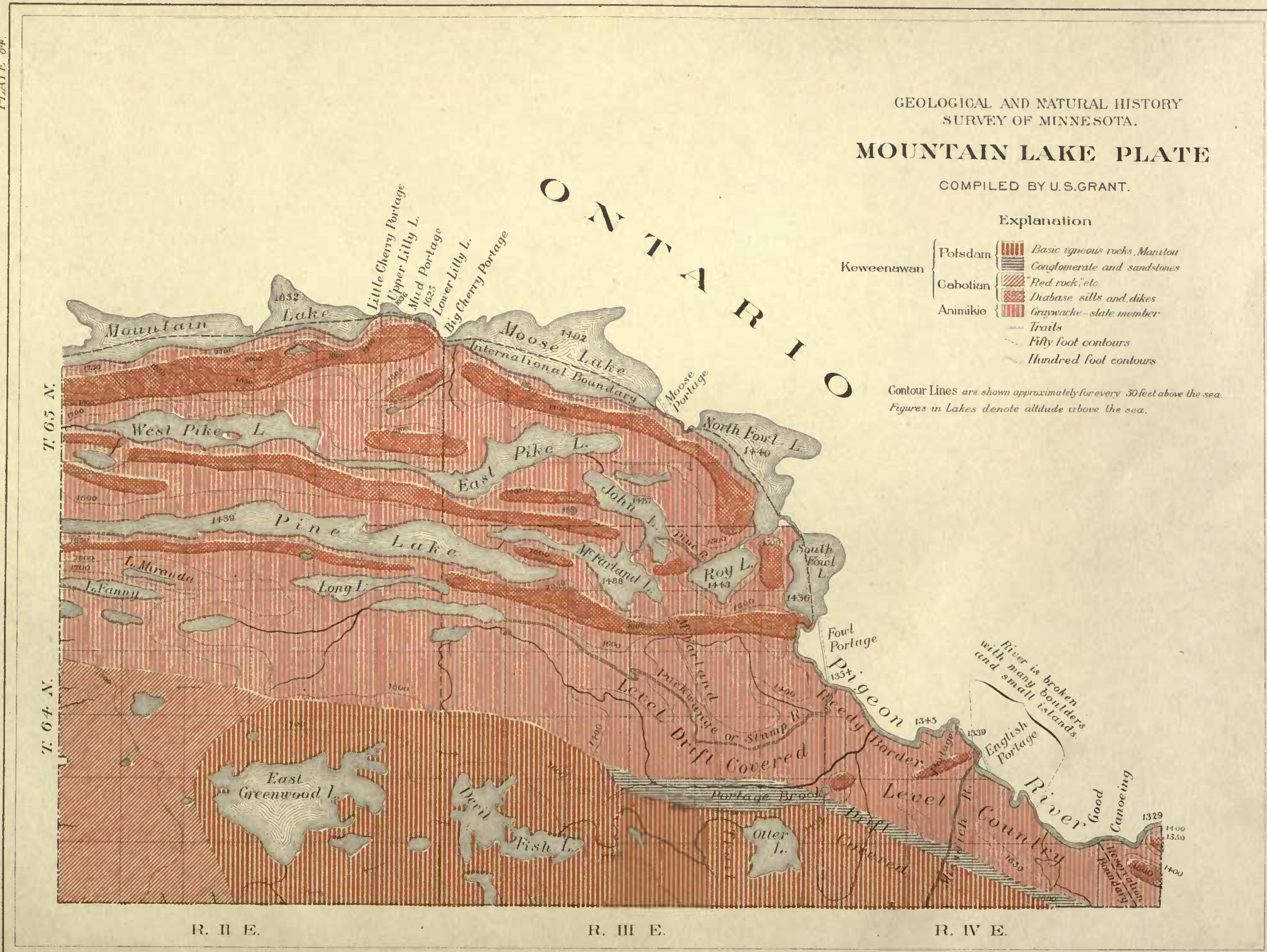

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
MOUNTAIN LAKE PLATE
COMPILED BY U.S.GRANT.
Explanation
Keweenawan
Potsdam
Basic igneous rocks, Manitou
Conglomerate and sandstones
Cabotian
"Red rock," etc.
Diabase sills and dikes
Animikie
Graywacke-slate member
Trails
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.
Figures in Lakes denote altitude above the sea.
ONTARIO
Mountain Lake
Little Cherry Portage
Upper Lilly L.
Mud Portage
Lower Lilly L.
Big Cherry Portage
Moose Lake
International Boundary
Moose Portage
North Fowl L.
West Pike L.
East Pike L.
John L.
Pine Lake
Pine R.
McFarland L.
Roy L.
South Fowl L.
L. Miranda
L. Fanny
Long L.
Fowl Portage
Pigeon
Reedy Border
River
Level Drift Covered
Puckwunge or Stump R.
McFarland
Portage Brook
English Portage
River is broken with many boulders and small islands.
Good Canoeing
Level Country
Reservation Boundary
East Greenwood L.
Devil Fish L.
Otter L.
Drift Covered
T. 65 N.
T. 64 N.
R. II E.
R. III E.
R. IV E.

PLATE LXXXV.

Pigeon Point Plate, 1899. N. H. Winchell.

There is no part of the state of equal size which is so mountainous. Along the northern boundary the Pigeon river descends, like nearly all the streams that enter lake Superior from Minnesota, rather suddenly from 600 to 700 feet. It presents, below the "grand portage," a continuous series of rapids and waterfalls as far as Pigeon River falls, below which, with some difficulty, small canoes can float in the river to the head of Pigeon bay, which is a fine harbor for large vessels.

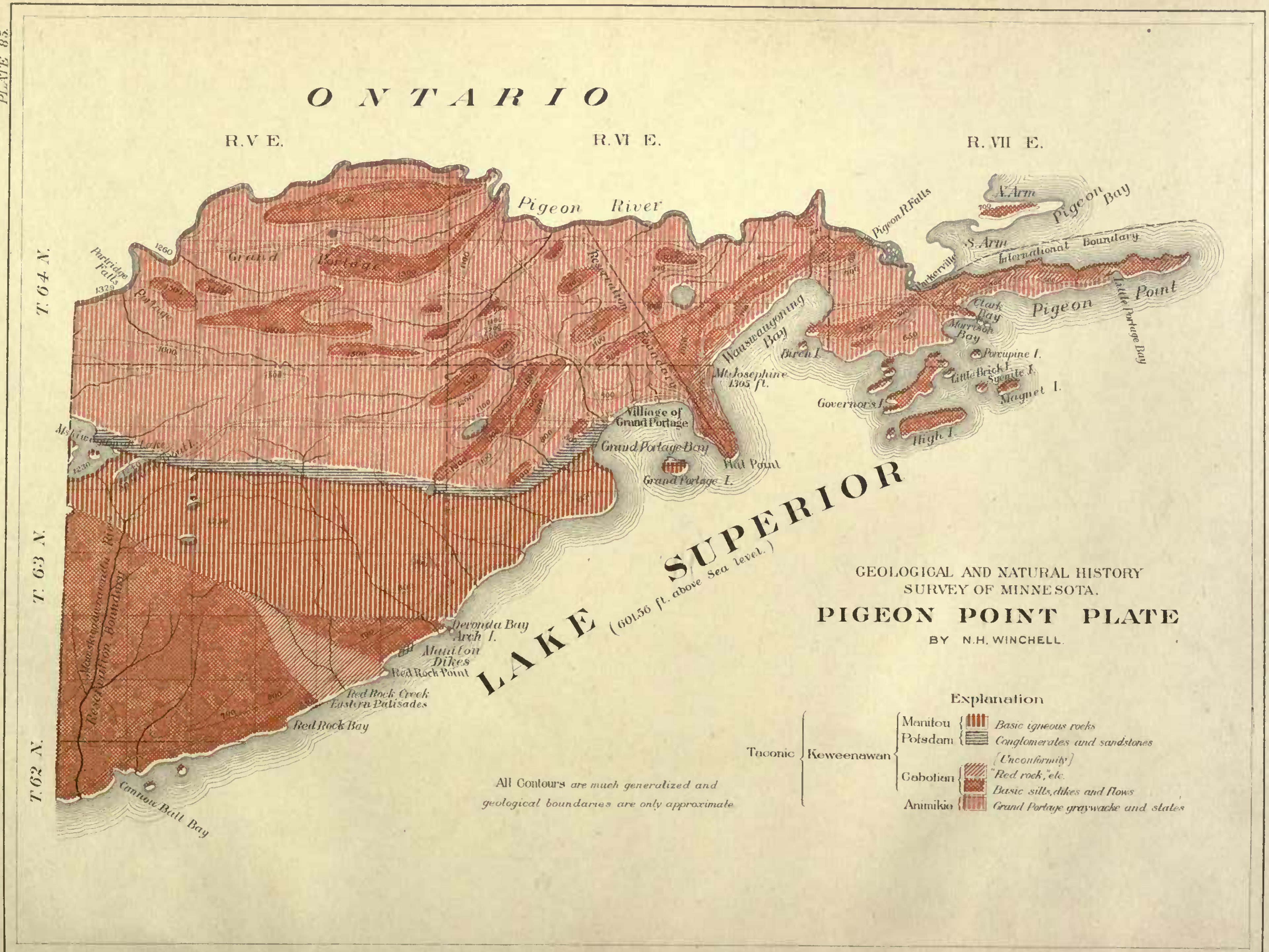
The hills are abrupt and rocky, consisting of great dikes of diabase and gabbro that lift their heads up through the slates which they penetrate sometimes with perpendicular walls from 50 to 200 feet above the slates which they cut. As these dikes, which are often several hundred feet wide, must have been confined between rock walls when the molten matter was intruded, there is evidence of the removal of that amount of strata of the Animikie by circumdenudation from the dikes. As there is no other place in the state where such a phenomenon is thus displayed, it is evident that the enclosing rock must have been one that was easily destroyed, quite unlike the Animikie that is known on the boundary line further west and on Pigeon point. This, indeed, is known to be the character of the Grand Portage graywacke. The hills are rudely arranged in ridges which extend easterly and northeasterly, though with exceptions, the most remarkable of which is the peninsula of Hat point, which is at right angles to the prevailing direction and may be in part a lava flow from mount Josephine.

The geological history of this little tract, so far as known at present, is about as follows, beginning at the bottom:

1. The Animikie strata were formed. On the area included within this plate only two of those parts of the Animikie that prevail further west are known, viz., the fissile black slates and the quartzyte, but there is, in addition, above (?) the Wauswaugoning quartzyte, the imperfectly slaty, greenish-gray member, or Grand Portage graywacke.

2. Surface eruptives and flows of basic rock, probably of minor importance. These are seen on some of the Lucille islands south of Pigeon point, where they seem to lie on the upper portion of the Animikie, cut by the great dikes of the country.

3. Epoch of profound igneous intrusion (Cabotian) forming the most of the dikes and sills of gabbro that invaded the Animikie. This event cannot probably be definitely separated from the last. The rocks of these two epochs doubtless run together in other places, especially where the ancient surface is preserved. But


ONTARIO
R.V E.
R.VI E.
R.VII E.
T. 64 N.
T. 63 N.
T. 62 N.
Pigeon River
Partridge Falls
Grand Portage
Reservation Boundary
Pigeon R. Falls
N. Arm
S. Arm
Pigeon Bay
International Boundary
Pigeon Point
Little Portage Bay
Clark Bay
Morrison Bay
Porcupine I.
Little Brick I.
Syenite I.
Magnet I.
High I.
Governors I.
Birch I.
Wauswaugoning Bay
Mt. Josephine 1305 ft.
Village of Grand Portage
Grand Portage Bay
Hat Point
Grand Portage I.
LAKE SUPERIOR (601.56 ft. above Sea level.)
Devonda Bay
Arch I.
Manitou Dikes
Red Rock Point
Red Rock Creek
Eastern Palisades
Red Rock Bay
Cannon Ball Bay
Reservation Boundary
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
PIGEON POINT PLATE
BY N.H. WINCHELL.
All Contours are much generalized and
geological boundaries are only approximate
Explanation
Taconic
Keweenawan
Manitou
Potsdam
Cabotian
Animikie
Basic igneous rocks
Conglomerates and sandstones
(Unconformity)
"Red rock," etc.
Basic sills, dikes and flows
Grand Portage graywacke and slates

throughout this area the denudation has been so profound that, so far as known, they are entirely distinct at the present surface, and the later date of the dikes seems to be plain. This great gabbro invasion gave origin to the red rocks of the region and their variations, by contact fusion of the sedimentaries.

4. Erosion interval, commencement of the Keweenawan clastic rocks (or Potsdam), conglomerate, quartzyte and sandstone of Potsdam age.

5. Eruptions more or less cotemporary with the fragmentals of No. 4, and very copious after the completion of the quartzyte, forming surface flows. Grand Portage island (Manitou).

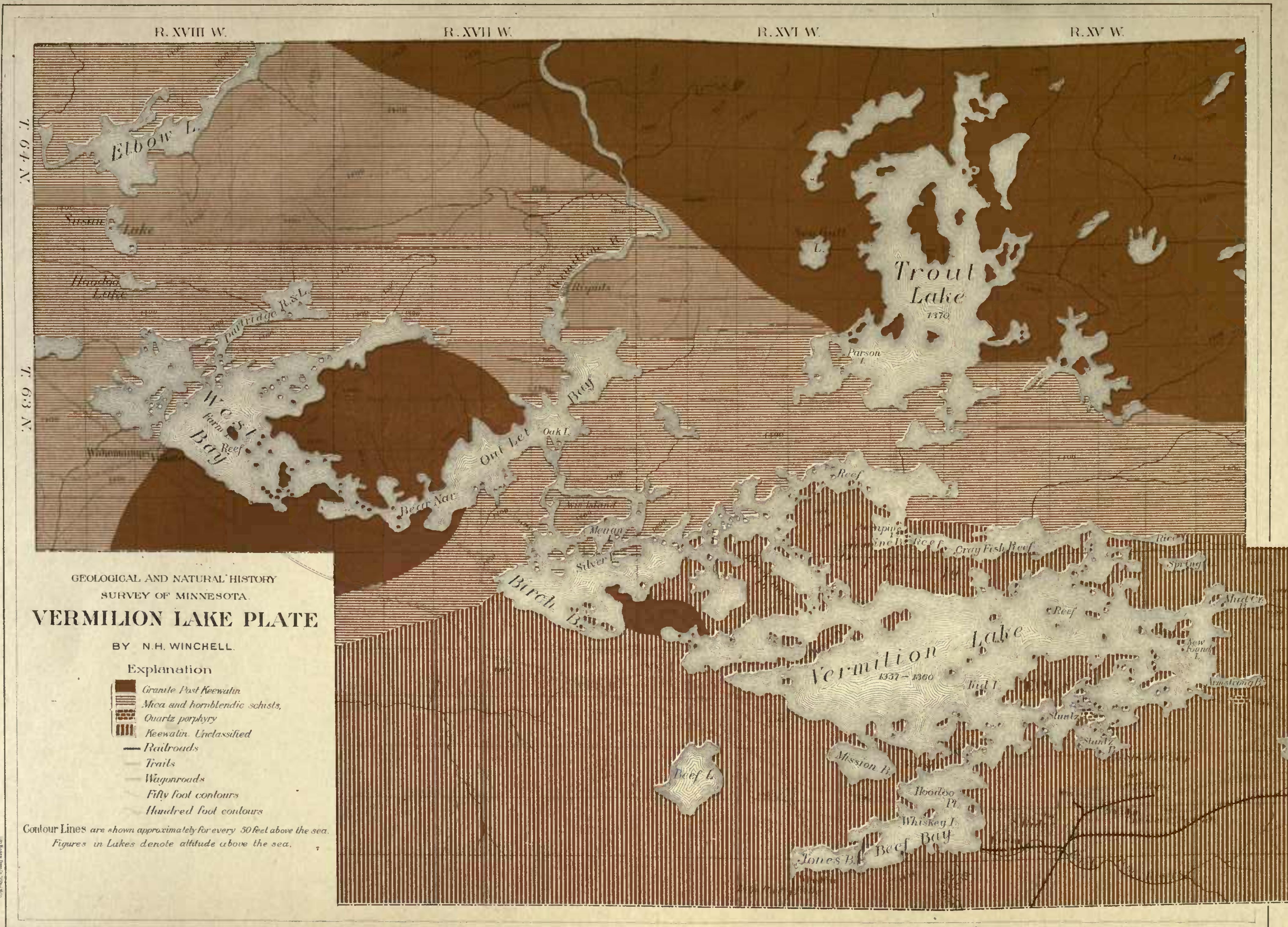
6. Dikes later than No. 5. So far as known the eruptives of No. 5 and No. 6 were only basic, mainly diabase, with amygdaloidal diabase. The dikes of No. 6 cut the surface flows of No. 5 on Grand Portage island. N. H. W.

PLATE LXXXVI.

The Vermilion Lake Plate, 1899. N. H. Winchell.

At Tower and along the south shore of Vermilion lake the bottom member of the Upper Keewatin, known as the Stuntz conglomerate, is well exposed. This conglomerate assumes very diverse characters. In much of the "south ridge" it contains many large jaspilyte masses, twenty, forty or fifty feet in diameter, and these are separated by scant green beds of schistose rock which present the aspect of dikes, but are, instead, the green sediment that was washed into the openings between these large masses. At other points near adjacent this green schist embraces many siliceous grains which are mainly composed of fine, detrital jaspilyte, and at still others it becomes a well banded graywacke. These fragmental jaspilyte masses were derived from the original jaspilyte of the Lower Keewatin, which is found at the west end of the "south ridge" and in the "north ridge." In many places this conglomerate is also composed largely of quartz-porphyry derived from older quartz-porphyry of the Lower Keewatin. This is its character at Stuntz island and along the lake shore west from that island. The largest of the rounded pieces are sometimes six to ten inches in diameter, but the size runs down to the smallest dimensions, thus forming a grit and graywacke. The native Lower Keewatin quartz-porphyry from which these pebbles are derived is found in the northern part of Stuntz island and at the corner where, in T. 62–15, the sections numbered 13, 14, 23 and 24 come together. There is almost an insensible gradation downward, in the conglomerate on Stuntz island, from coarse to fine. Hence, when the contact occurs between the Upper Keewatin and the Lower, it is very difficult to determine the precise place of contact. The debris from the original quartz-porphyry, when hardened, is much like the rock from which it was derived. This fact is repeated where the conglomerate lies on greenstone, and where it lies on granite. It suggests that between the Upper Keewatin and the Lower there occurred a long period of land surface, during which the Lower Keewatin was decayed to great depth, and that on submergence at the opening of the Upper Keewatin the decayed materials were not entirely removed and assorted by transporting and sedimentary action. This phenomenon is also well exhibited at the bottom of the Cretaceous in the Minnesota valley and in Mower county, where the kaolin is evidently in part residual and in part sedimentary.

Anyone who studies the jaspilyte should bear in mind that there is a sedimentary jaspilyte, belonging in the Lower Keewatin, as well as one which was originally a basic rhyolyte. The former is interstratified with green schists and varies like a


R. XVIII W.
R. XVII W.
R. XVI W.
R. XV W.
T. 64 N.
T. 63 N.
Elbow L.
Susan Lake
Trout Lake
1370
Parson I.
West Bay
Farm Reef
Out Let
Oak I.
Bay
Bear Nar.
Birch B.
Silver
Reef
Cray Fish Reef
Spring
Vermilion Lake
1357 – 1360
Reef
Kid I.
New Found I.
Armstrong B.
Stuntz
Stuntz Pt.
Mission B.
Hoodoo Pt.
Whiskey I.
Beef Bay
Jones B.
Beef L.
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
VERMILION LAKE PLATE
BY N.H. WINCHELL.
Explanation
Granite Post Keewatin
Mica and hornblendic schists,
Quartz porphyry
Keewatin. Unclassified
Railroads
Trails
Wagonroads
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.
Figures in Lakes denote altitude above the sea.

sedimentary rock, becoming siliceous slates and siliceous argillyte. The latter is curled and banded like a fluidal molten rock, but it is not, so far as known, associated with structural alternations of green schist or other clastic materials. This is supposed to have been originally a basic obsidian, quite like the obsidians of the Mesabi range, ejected in submarine conditions.* The effect of such igneous action on the ocean was the chemical precipitation of silica and iron. Such precipitated silica not only permeated and replaced the most of the noncrystalline matter of the obsidian, but, when abundant and continued long enough, it formed sedimentary, banded jaspilyte. These two are not to be confounded with the fragmental secondary jaspilyte above referred to as belonging to the bottom of the Upper Keewatin. The iron itself was also probably chemically precipitated by the ocean, in part, and was derived in part from the alteration of the basic glass. Occasionally a taconitic sand, at least the taconitic structure, has been found in connection with the jaspilyte of the Vermilion range, indicating the Lower Keewatin accumulation of obsidian sands in the vicinity of obsidian ejection in a manner similar to that already described along the Mesabi range.

N. H. W.

*This distinction was not made in the chapter devoted to this plate in volume iv, but was included in the descriptions in volume v.

PLATE LXXXVII.

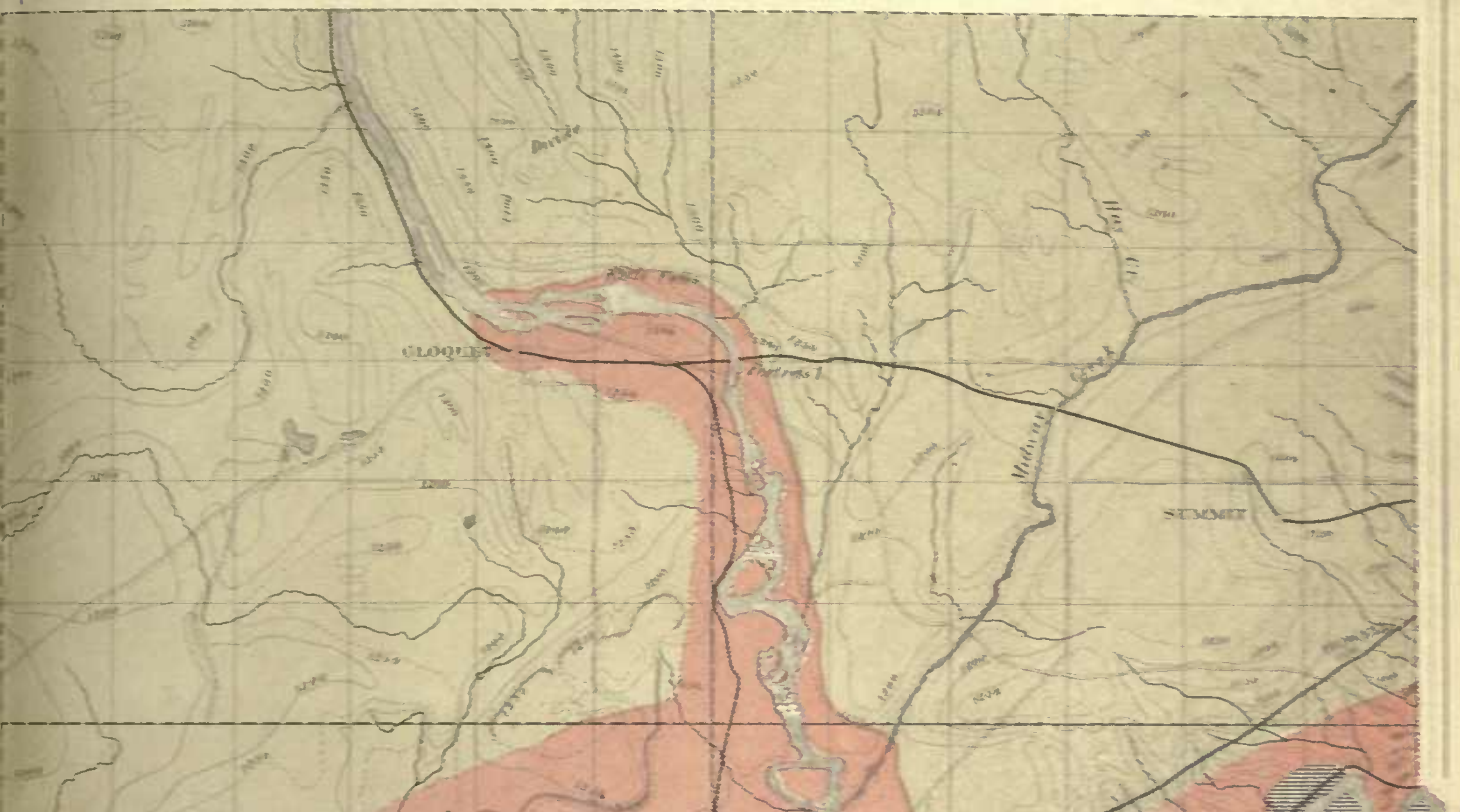
THE CARLTON PLATE, 1899. N. H. WINCHELL.

The valley of Otter creek is wide and terraced, at least as far west as sec. 17, T. 48–17, indicating that it was not formed by the present stream. Above that point the stream runs on the drift surface without marked terraces. The old terraced valley continues southwestward and south, and blends into the valley of the Blackhoof river, which runs south to the Nemadji, there being thus a continuous wide terraced valley running from the St. Louis river at Carlton into the Blackhoof and Nemadji valleys. This was during the waning of the Glacial epoch, but when the Lake Superior ice-lobe still remained and thrust its western margin upon Carlton county, thus forcing the St. Louis river into the glacial lake Nemadji. At a previous date this ice-lobe had been extended slightly further west and the St. Louis river was then driven from the Lake Superior basin altogether. Its waters, at first forming a small lake at a higher level than lake Nemadji, were carried across the divide in Carlton county to the Moose river and reached the Mississippi river through the St. Croix valley. The early, smaller, glacial lake has been named lake St. Louis.

When finally the ice-lobe had retired far enough to uncover the lower outlets of lake Superior further east, the St. Louis river, below Carlton, took its present route to the sea, flowing at first over the clay that had been deposited by lake Nemadji. Its excavation through this clay and into the underlying till, down to the rocks which now form the rapids, has been done since, while above Carlton the river was gnawing into the rocks over which it flows during that earlier period while it fed the glacial lakes St. Louis and Nemadji. The difference, however, in the amount of erosion of the rocks, above and below Carlton, is hardly observable, except when the river comes into contact with some older bluffs, as at and above Fortress island, where the river runs in a shallow, rock-cut gorge in thin slates.

The rocks of this plate are supposed to belong to the Animikie, and to the Keweenawan, the latter being of Potsdam age. The former are abundantly uncovered along the St. Louis valley, and about Carlton and Thomson they form numerous short monoclinals whose strata dip toward the south. These strata have not only been tilted but they have been pressed and sheared with a crushing force which has greatly deformed them. These features are specially observable at Cloquet. These strata are also penetrated by numerous Keweenawan dikes, most of them running nearly north and south. One of the largest of these is visible at the railroad where it crosses the St. Louis just north of Fortress island, on the west side. Others appear at Carlton and at Thomson, and below Thomson, where they cross the river. These and the diabasic gabbro rock which appears in the St. Louis valley a little to the east of this area are referred to the Cabotian of the Keweenawan. N. H. W.

PLATE 47



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

CARLTON PLATE

BY N. H. WINCHELL

Explanation

Glacial	Till, rolling moraine	Roads and Trails
Potsdam	Sandstones and conglomerates	Railroads
Animikie?	Slates and graywackes	Fifty foot contours
	Ancient river terrace	Hundred foot contours

Contour Lines are shown approximately for every 50 feet above the sea.

PLATE LXXXVIII.

THE DULUTH PLATE, 1899. N. H. WINCHELL.

The best synopsis that can be given of the geology represented by this plate is probably that which is derived from the record of the deep well, *sunk for gas*, at the Short Line Park station a few years ago.

1. Previous to reaching the depth of 231 feet no drillings were preserved, but this interval is supposed to have been occupied by red sandstone and shale like that seen in the river banks adjacent, perhaps with more or less of eruptive material, 231 feet.

2. The first drillings preserved are of eruptive nature and this rock becomes amygdaloidal trap, or surface lavas. There is then an interval of 104 feet not represented by drillings, supposed to be occupied mainly by eruptive strata, but probably embracing also fragmental materials, such as reddish conglomerates and sandstones, erosion products of cotemporary eruptions. Below this uncertain interval, as well as above it, was rock which was plainly a surface eruptive. If these all be put together we have, eruptives and surface flows, 217 feet.

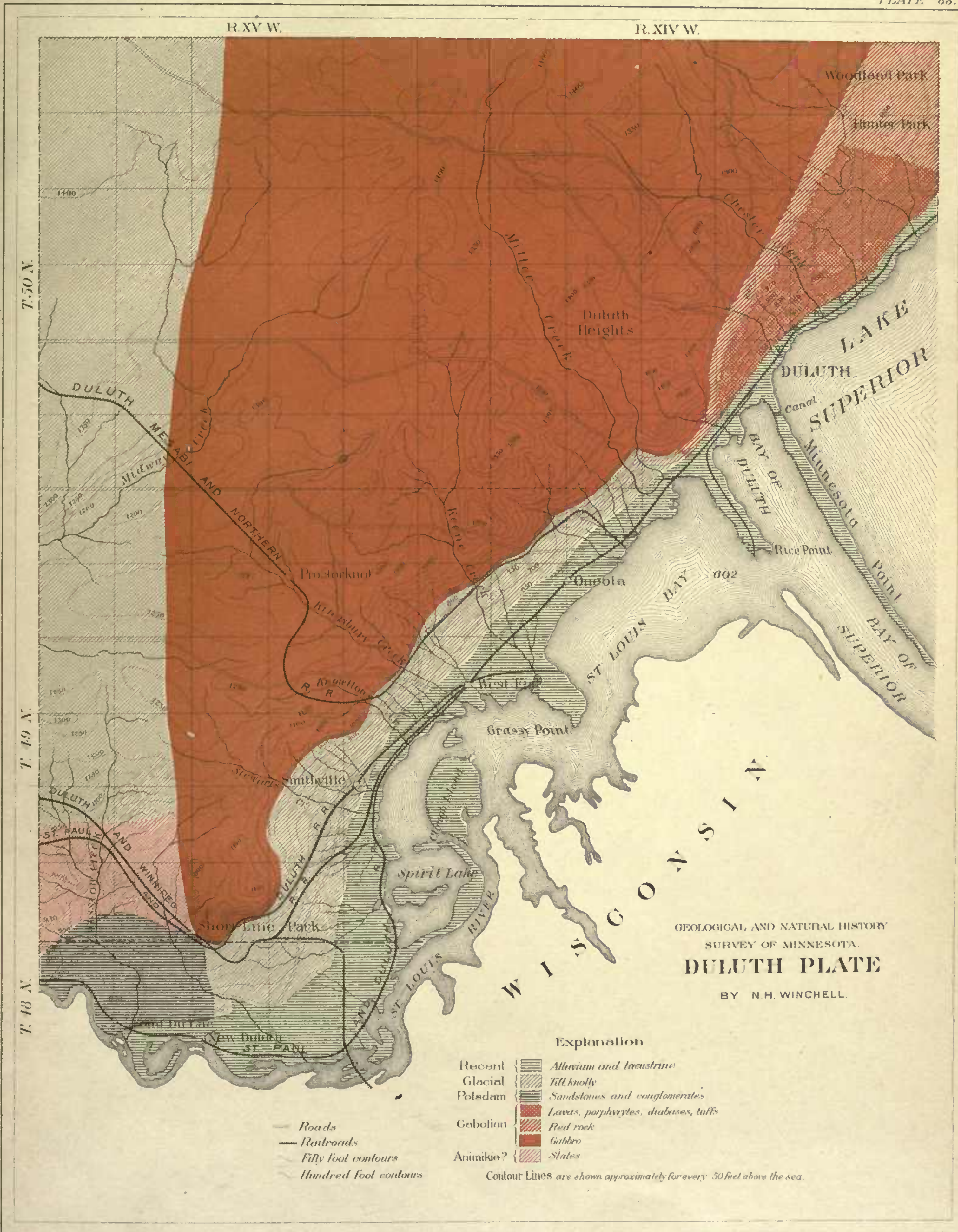
3. Below these eruptives follows a series of hard quartzytes and quartz conglomerates, with but little eruptive material, having a thickness of forty-eight feet. The striking similarity of this to the pyritiferous white quartz conglomerate seen in the left bank of the St. Louis river, a little west of Short Line park, leaves no alternative but to parallelize it with that rock. But here, instead of lying on the Thomson slates, it lies on another series of eruptives. Hence, quartz conglomerate and quartzyte, 48 feet.

4. These lower eruptives are amygdaloidal, and resemble greatly those seen at Duluth and eastward to Chester creek, and it seems necessary to parallelize them with the flow rocks at Duluth, 91 feet.

5. Below this second series of eruptives is found the Thomson slate, the supposed equivalent of the Animikie. This formation, although penetrated by the drill to the bottom of the well 1,517½ feet below the natural surface, was not pierced at that depth. These parts may be put together succinctly as follows:

1. Fond du Lac red sandstones and shale, Potsdam,	231	feet
2. Surface eruptives, Manitou, Potsdam,	217	"
3. Pyritiferous quartzyte and quartz conglomerate, Puckwunge, Potsdam,	48	"
4. Surface lavas, as at Duluth, Cabotian,	91	"
5. Thomson slates, Animikie(?),	930½	"
Total,	1,517½	feet

It is to be noted that the Fond du Lac sandstones are chronologically separated from the coarse pebbly conglomerate on which they lie at the river by a series of


R.XV W.
R.XIV W.
T. 50 N.
T. 49 N.
T. 48 N.
Woodland Park
Hunter Park
Chester Creek
Miller Creek
Duluth Heights
DULUTH
Canal
LAKE SUPERIOR
BAY OF DULUTH
Minnesota Point
Rice Point
BAY OF SUPERIOR
ST LOUIS BAY
602
Oneota
Keene Creek
DULUTH MESABI AND NORTHERN
Midway Creek
Proctorknot
Kingsbury Creek
Knowlton R.R.
West End
Grassy Point
Stewarts Cr.
Smithville
Spirit Lake
ST. LOUIS RIVER
Short Line Park
DULUTH ST. PAUL AND WINNIPEG
Mission Creek
Fond Du Lac
New Duluth
ST. PAUL
DULUTH R.R.
WISCONSIN
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
DULUTH PLATE
BY N.H. WINCHELL.
Explanation
Recent { Alluvium and lacustrine
Glacial { Till, knolly
Potsdam { Sandstones and conglomerates
Keweenawan { Lavas, porphyrites, diabases, tuffs
Red rock
Gabbro
Animikie? { Slates
Roads
Railroads
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea.

surface eruptives. This marks an important physical event as transpiring in the immediate neighborhood between the date of the Fond du Lac sandstones and that of the quartzyte and conglomerate. This physical change in the environment is indicated by the change in the nature of the accumulating cotemporary sediments, viz., from coarse, siliceous sediments to sediments of eruptive fragments, although, at the river, there is no apparent stratigraphic break.

The gabbro, as such, is wanting, and in its place is a series of eruptive basic flows which are identical with those seen at Duluth along the lake shore. This indicates that the gabbro intrusion was, at the site of this deep well, represented by a succession of extrusions at the surface.

The bottom of this lower series of eruptives is characterized by the usual features where the gabbro comes into contact with the Animikie, viz., fusion and blending of the fragmental rocks with the basic eruptives, producing two sorts of igneous rock, one acid, the result of fusion of the clastics, and the other basic, from a deep source.

N. H. W.

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