THE

GEOLOGICAL

AND

NATURAL HISTORY

SURVEY OF MINNESOTA.

THE

FIRST ANNUAL REPORT

FOR THE YEAR 1872

By N. H. WINCHELL, State Geologist.

SUBMITTED TO THE PRESIDENT OF THE BOARD OF REGENTS
DECEMBER 31, 1872.

[SECOND EDITION]

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NOTE.—This edition is identical with the original publication, except in typography, and in the lists of elevations on various railroads, which have been revised and corrected and referred to sea-level, through lake Superior at 602 feet. The pagination begins with number 17, in order to agree with the original.—N. H. WINCHELL.

ADDRESS.

ST. ANTHONY, MINN.,
Dec. 31, 1872.

Hon. J. S. Pillsbury, president of the board of regents of the University of Minnesota:

DEAR SIR :—I have the honor herewith to present the first annual report of progress on the geological and natural history survey of the state, required by the provisions of the law creating the same. The field work covered by this report is that performed by myself alone between the first of September and the closing of the season, on the 12th day of November, by the first fall of snow. The means at my disposal not admitting of the employment of assistants, it has only been possible to make a general reconnoissance of the state by visiting those parts accessible by railroad. In that way I have succeeded in making a connected section of observed strata from the trap and granite rocks, which lie at the base of our geological system, to the *Galena limestone*, in the Lower Silurian, including also about forty feet of the latter. Between the *Galena* and the *Cretaceous* no intervening rocks have been seen, but it is probable that the remainder of the Lower Silurian, including the *Maquoketa shales* and the *Niagara limestone*, which in the Northwest seems to constitute the Upper Silurian, as well as the lower portions of the Devonian, are in place in some parts of the southern portion of the state. A few sections have also been taken in the *Cretaceous* clays and sandstones in the southern part of the state. Developments of considerable interest and economical importance have already been made in connection with this series of rocks, as detailed in the accompanying report; and it is believed that they will afford in the future progress of the survey some of the best exemplifications, not only of the scientific value, but also of the practical usefulness of our investigations.

The small geological map of the state accompanying this report is intended to embody all that is known concerning the geographical outlines of the various formations embraced within the state. With the exception of the southeastern part of the state, the outlines of the geology of which have been more minutely laid out by Mr. W. D. Hurlbut, of Rochester, Minn., this map is to be regarded as only an approximation to the actual bearing of the strata, the boundaries of which are marked by tortuosities which it will be the future work of the survey to carefully trace out.

It becomes my pleasant duty to acknowledge the active interest and aid of the president of the university in the initiation of the survey in various matters of administrative courtesy touching its relation to the university. Rooms have been provided in the university building for the storage of specimens and for laboratory work; and the nucleus of a geological museum has already been established.

Mr. W. D. Hurlbut, of Rochester, who, as a pioneer in the scientific development of the geology of southern Minnesota, has gathered information which it would require several seasons of field work for one man to collect, has freely aided me by giving all the information in his possession, and has spent considerable time gratuitously in guiding me to points of interest. The preliminary map accompanying this report shows the minuteness with which he has observed the geological boundaries in that part of the state.

Prof. Wm. F. Phelps, of the normal school at Winona, has given much information concerning that section of the state, and has accompanied me to various places of geological importance. His collection of fossils from the *Trenton* and other Silurian rocks stored in the museum of the normal school, has been opened for examination and study. He has donated to the geological museum of the university plaster casts of some of the largest and most perfect specimens of trilobites ever found in the state of Minnesota.

Mr. A. J. Hill, of St. Paul, has enjoyed unusual facilities for collecting the most complete information concerning the relative altitudes of different parts of the state as shown by railroad profiles, and has tendered to the survey the free use of all his tables.

Dr. H. H. Guthrie, of St. Charles, and Mr. A. Van Vorhes, of Stillwater, guided me in making observations at those places; giving me much valuable information.

Mr. Frank Wilson, of Mantorville, has placed in the university museum a large collection of fossils from the *Galena limestone*, on temporary deposit. For the benefit of the geological survey he has submitted them for examination and nomenclature.

The St. Paul & Sioux City, and Sioux City & St. Paul R. R., the Northern Pacific R. R. and the Southern Minnesota R. R. have materially aided in the prosecution of the field-work by granting continuous passes on their roads. The Winona & St. Peter R. R. has also granted trip passes on application.

In general the people of the state, so far as I have come in contact with them, have manifested much interest in the survey, and expressed a willingness to aid in its progress in every way in their power.

Allow me to thank you for the cordiality with which you have officially counseled and aided me in making the preliminary reconnoissance, and for personal favors at your hands.

Very respectfully,

N. H. WINCHELL,
State Geologist.

I.

HISTORICAL SKETCH AND LIST OF PUBLICATIONS RELATING TO THE GEOLOGY AND NATURAL HISTORY OF MINNESOTA.

The earliest published accounts of the natural features and resources of Minnesota are found in the writings of the Jesuit missionaries. These, however, are generally too vague or too general in their statements to be of much scientific value. The first printed account and distinct mention of the Mississippi river, within the limits ot Minnesota, seems to be that of Father Hennepin, who visited the falls of St. Anthony in 1680, and gave them their name, although Father Marquette discovered the river at lower points as early as 1673. Father Hennepin's book, published at Utrecht in 1679, has the following title: *Voyage ou nouvelle decouverte d' un tres grand pays dans L' Amerique entre nouveau Mexique et la mer glaciale par le R. P. Louis Hennepin, avec toutes les particularitez de ce Pais, & de celui connue sous le nom de La Louisiane; les advantages qu' on en peut tirer par l' etablissement des colonies; enriche de Cartes Geographiques: augmente de quelques figures en taille douce;—avec un voyage qui contiente une Relation exacte de l'Origine, Moeurs, Coutumes, Religion, Guerres, & Voyages des Caraibes sauvages des Isles Antilles de l'Amerique, faite par le Sieur De La Borde, tiree du Cabinet de Monsr. Blondel.*

The voyage proper of Hennepin is divided into seventy-six chapters. The following titles show the relations of some of these chapters to the state of Minnesota.

* * * * * * *

XXXVI. Depart d'Auteur en Canot du fort Crevecoeur avec les deux hommes, dont il a ete parle, pour se rendre aux Nations eloignees.

XXXVII. Quels ont ete les motifs que l'Auteur a eus ci-devant de cacher les memoires qu' il avoit de cette Decouverte & de ne les pas inferer dans la Description de sa Louisiane.

XXXVIII. Continuation' du voyage de l'Auteur sur le Fleuve Meschasipi.

XXXIX. Raisons qui nous obligerent de remonter le Fleuve Meschasipi sans aller plus loin vers la Mer.

XL. Depart de Koroa sur le Fleuve Meschasipi.

XLI. Description de la beaute du Fleuve Meschasipi, des terres, qui le bordent de part & d'autre, & qui sont d'un beaute' ravissante & des Mines de cuivre, de plomb, & de carbon de terre qu'on y a trouva.

XLII. Description' des divers langes de ces peuples & de leur soumission a' leurs Chefs; des Mannieres differentes de ces peuples de Meschasipi d'avec les sauvages du Canada & du peu de fruit, qu' on peut esperer pour la Religion chretiene parmi eux.

XLIII. Description de la peche vue nous faissons des etourgeons. Crainte de nos gens qui ne vouloient point passer en remontant pres de l' embouchure de la Riviere des Illinois, & du changement des terres et du climat en allant vers le Nord.

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LIX. Les sauvages sont halte au dessus du saut de St. Antoine de Padoue. Ils se trouvent en necessite de vivres; l' Auteur va avec le Picard a' Riviere d' Ouisconsin. Aventures de leur voyage.

LX. Chasse des Tortues, le canot enleve' a' l' Auteur par un vent impetueux, ce qui le jette dans un grande necessite avec son compagnon de voyage.

Memoire sur les Moeurs, Coutumes, et Religion des sauvages de l' Amerique Septentrionale, par Nicolas Perrot, publie pour la premiere fois, par le R. P. J. Tailhan de la compagne de Jesus, 1864. 12mo. 341 pp.

This valuable memoir remained in manuscript from 1670 till 1864 without publication.

In the latter part of the seventeenth century Baron La Hontan, Lord Lieutenant of the French colony at Placentia, Newfoundland, traveled over much of the Northwest, visiting the territory now embraced in Minnesota, and describing the nations and many of the natural features of the country. His book is entitled: *New Voyages to North America, containing an account of the several na-*

tions of that vast continent, their customs, commerce and way of Navigation upon the Lakes and Rivers; the several attempts of the English and French to dispossess one another, with the relations of the miscarriage of the former; and the various adventures between the French and the Iroquese, confederates of England, from 1683 to 1694.

Historical Collections of Louisiana, embracing translations of many rare and valuable documents relating to the natural, civil and political history of that state. Part IV. Redfield, New York, 1852, 8vo. pp. 268. (map.) Contains original narratives by Marquette, Allouez, Membre, Hennepin and Douay, relating to the discovery and exploration of the Mississippi river.

Early voyages up and down the Mississippi. By Cavalier, St. Cosme, Le Sueur, Gravier and Geugnas, with an introduction and notes by John G. Shea, Albany, 1861, 4to. pp. 191.

The travels of Jonathan Carver were performed in 1766,'67 and '68. His may be regarded the first contribution to the natural history of the country bordering on the upper Mississippi. His work is printed under the title of: *Three Years' Travels throughout the interior parts of North America.* Containing an account of the lakes, islands and rivers, cataracts, mountains, minerals, soil and vegetable productions of the northwest regions of that vast continent, with a description of the birds, beasts, reptiles, insects and fishes peculiar to that country, together with a concise history of the genius, manners and customs of the Indians inhabiting the lands that lie adjacent to the heads and west of the river Mississippi; and an appendix describing the uncultivated parts of America that are the most proper for forming settlements; by Jonathan Carver, captain of the provincial troops in America; 16mo. pp. 280.

Mr. Schoolcraft's first expedition to the sources of the Mississippi river was performed in 1820. His report was published under the following title: *Narrative Journal of travels from Detroit northwest through the great chain of lakes to the sources of the Mississippi river in 1820.* By Henry R. Schoolcraft, performed as a member of the expedition under Governor Cass, embellished with a map and eight copper plate engravings, 8vo. pp. 419.

In the year 1823 the United States Government ordered an expedition to the sources of the St. Peter river, lake Winnepeg and lake of the Woods, the report of which was published by congress under the following title: *Narrative of an expedition to the sources* *of the St. Peter river, lake Winnepeek, lake of the Woods, &c.*, performed in the year 1823 by order of Hon. J. C. Calhoun, secretary of war, under the command of Stephen H. Long, U. S. topographical engineers. 2 vols., pp. 458 and 248, with an appendix of 156 pages.

CONTENTS OF VOLUME I.

Chapter I. Departure from Philadelphia—Geology of the Alleghanies—Cumberland road—Wheeling.

Chapter II. Zanesville—Salt and iron works—Columbus—Piqua—Indian antiquities—Ohio canals—Fort Wayne.

Chapter III. Description of Fort Wayne and vicinity—Fur trade—Potawotamies.

Chapter IV. Cary mission house—Lake Michigan—Chicago.

Chapter V. Rock river—Menomones—Geology of the country west of lake Michigan—Prairie du Chien—Sauks and Foxes.

Chapter VI. Prairie du Chien—Indian remains—Division of the party—Mississippi—Dacotah villages—Fort St. Anthony falls—River St. Peter.

Chapter VII. Geology of the Mississippi—The expedition ascends the St. Peter's—Character of the country—Arrival at lake Traverse.

Chapter VIII. Account of the Dacotahs, or Sioux Indians—Their division into tribes—Their numbers, language, manners and customs—Notice of Watonwan, principal chief of the Yanktonian tribe—Description of the Columbia Fur Company's establishment at lake Traverse.

CONTENTS OF VOLUME II.

Chapter I. The party leave lake Traverse—They fall in with large herds of buffalo—Observations upon the rovings of this animal—Meeting with a war party of the Wahkpahotas who manifest hostile dispositions—Arrival at Pembina.

Chapter II. Fort Douglas and Lord Selkirk's colony—Bark canoes—Lake Winnepeek—Fort Alexander—River Winnepeek—Rapids—Portages—Fine falls—Lake of the Woods—Northwesternmost point of the Boundary line—Rainy Lake river and lake—Fort—Series of rapids and falls—Dividing ridge—Falls of Kamanatekwoya—Arrival at Fort William.

Chapter III. Account of the Chippewa Indians—Their usages, manners and customs.

Chapter IV. Departure from Fort William—Trap formations on lake Superior—Michipecotton house—Arrival at Sault St. Marie—Conclusion of the journey.

Chapter V. General description of the country traversed by the expedition, designed as a topographical report to the war department, by S. H. Long, U. S. T. E. (Divided into seven chapters.)

CONTENTS OF THE APPENDIX.

Part I. *Natural History.* Zoology by Thomas Say—Catalogue and descriptions. Botany by Lewis D. de Schweinitz.

Part II. *Astronomy.*

Part III. *Meteorology.*

Part IV. *Indian Vocabularies.*

Mons. J. C. Beltrami, who started out as a member of Major Long's party of exploration to the sources of the St. Peter river, parted from him, and exploring the Mississippi to its source, published his observations under the following title: *La Decouverte des sources du Mississippi, et de la riviere Sanglante.*

Descriptions du cour entier du Mississippi * * * * *aussique du cour entier d l' Ohio, Observations critico-philosophiques sur les moeurs, la religion, les superstitions, les coutumes, les armes, les chasses, la guerre, la paix, le nombrement, l'origine, &c., &c,, de plusieurs nations indiennes* * * * * * *Preuves evidentes que le Mississippi est la premiere riviere du monde.* Par J. C. Beltrami, Membre de plusieurs academies, 1824, pp. 327.

Narrative of an expedition through the Upper Mississippi to Itasca lake, the actual source of this river, embracing an exploratory trip through the St. Croix and Burntwood (or Brule) rivers in 1832, under the direction of Henry R. Schoolcraft. (Published by Harper & Brothers,) pp. 307, 8vo.

Besides the narrative this book embraces an appendix, as follows:

I. *Natural History.* 1. List of shells collected by Mr. Schoolcraft. By William Cooper. 2. Localities of minerals observed in 1831 and 1832 in the Northwest. By H. R. Schoolcraft. 3. Localities of plants collected in the northwestern expeditions of 1831 and 1832. By Douglass Houghton, M. D., surgeon to the expedition.

II. *Indian languages.* Part of a course of lectures on the grammatical structure of the Indian languages, delivered before the St. Mary's committee of the Algic society. By H. R. Schoolcraft.

III. *Official reports*, embracing among others a report of Dr. Houghton on the copper of lake Superior; dated Fredonia, N. Y., Nov. 14, 1831.

Summary narrative of an exploratory expedition to the sources of the Mississippi river in 1820, resumed and completed by the discovery of its origin in Itasca lake in 1832. With appendices comprising the original report of the copper mines of lake Superior, and observations on the geology of the lake basins and the summit of the Mississippi; together with all the official reports and scientific papers of both expeditions. By Henry R. Schoolcraft. Philadelphia. Lippencott, Grambo & Co., 1855.

Besides the narrative, the following scientific papers are included in the appendix :

I. *Of the expedition of* 1820.

Results of observations for latitudes and longitudes during the expedition of 1820. By David B. Douglass, captain of engineers, U. S. A.

Report on the copper mines of lake Superior. By H. R. Schoolcraft.

Observations on the mineralogy and geology of the country embracing the sources of the Mississippi river and the great lake basins. By H. R. Schoolcraft.

Report on the value and extent of the mineral lands of lake Superior, in reply to a resolution of the U. S. Congress. By H. R. Schoolcraft.

Rapid glances at the geology of western New York beyond the Rome summit, in 1820. By H. R. Schoolcraft.

A memoir on the geological position of a fossil tree in the secondary rocks of Illinois. Albany, N. Y. E. & E. Hosford, pp. 18. 1822. By H. R. Schoolcraft.

List of plants collected by Capt. D. B. Douglass at the sources of the Mississippi river. *Am. Jour. Sci. and Arts*, vol. 4, p. 56. By John Torrey, M. D.

A letter embracing notices of the zoology of the Northwest. Addressed to Dr. Mitchell on the return of the expedition. By H. R. Schoolcraft.

Species of bivalves, collected by Mr. Schoolcraft and Captain

Douglass in the Northwest, published in the 6th volume of the Am. Jour. Sci. pp. 120—259, By D. H. Barnes.

Fresh water shells, collected by Mr. Schoolcraft, in the valleys of the Fox and Wisconsin rivers. Am. Phil. Trans., vol 5. By Mr. Isaac Lea.

Summary remarks respecting the zoological species noticed in the expedition. By Dr. Samuel L. Mitchell.

Mus bursarius. Medical Repository, vol. 21, p. 248. By Dr, Samuel L. Mitchell.

Sciurus tre-decem-striatus. Med. Repos., vol. 21. By Dr. Samuel L. Mitchell.

Proteus of the Lakes. Am. Jour. Sci., vol. 4. By Dr. Samuel L. Mitchell.

Memoranda of climatic phenomena, and the distribution of solar heat in 1820. By H. R. Schoolcraft.

II. *Of the expedition of* 1832.

Limits and range of the *Cervus sylvestris* in the northwestern parts of the United States. Northwest Journal. By H. R. Schoolcraft.

Description of the *Fringilia vespertina* discovered by Mr. Schoolcraft in the Northwest. Annals of the New York Lyceum of Natural History. By William Cooper.

List of shells collected by Mr. Schoolcraft during his expedition to the sources of the Mississippi river in 1832. By William Cooper.

List of species and localities of plants collected during the exploring expeditions of Mr. Schoolcraft in 1831 and 1832. By Douglass Houghton, M. D., surgeon to the expeditions.

A report on the existence of deposits of copper in the trap rocks of Upper Michigan. By Douglass Houghton.

Remarks on the occurrence of native silver and the ores of silver in the stratification of the basins of lakes Huron and Superior. By H. R. Schoolcraft.

A general summary of localities of minerals observed in the Northwest. By Henry R. Schoolcraft.

Geological outlines of the valley of Takwymenon, in the basin of lake Superior. By H. R. Schoolcraft.

Suggestions respecting the geological epoch of the deposit of the red sandstones of the St. Mary's falls of Michigan. By H. R. Schoolcraft.

Table of geographical positions observed in 1836. By J. N. Nicollet.

Report of a geological reconnoissance, made in 1835 from the seat of government by the way of Green bay and the Wisconsin territory to the Coteau de Prairie, an elevated ridge dividing the Missouri from the St. Peter's river. By G. W. Featherstonhaugh, U. S. geologist. Dated April 22, 1836. Printed by order of the senate. Doc. 333, pp. 168.

Notes on the Wisconsin territory, particularly with reference to the Iowa district or Black Hawk purchase, with a map. By Lieut. Albert Lea, U. S. dragoons, 1836, 16mo. 53 pages, close print.

Report intended to illustrate a map of the hydrographical basin of the Upper Mississippi river. By J. N. Nicollet in employ under the bureau of the corps of topographical engineers, and under instructions dated April 7, 1838. pp. 170, 26th Congress, 2nd session, senate, [237]. Printed Feb. 16, 1841, 500 copies ordered. Also 28th Congress, 2nd sess., House of reps. [52], Jan. 11, 1845, 1500 copies ordered.

This valuable document on the Upper Mississippi consists of:—

Part I. Physical geography of the region embraced within the map, with incidental notes on its geology, mineralogy and botany.

Part II. Comprises: determination of altitude by barometer; determination of time; determination of latitude; determination of longitude; a table showing results of observations.

[A sketch of the early history of St. Louis was prepared by Mr. Nicollet to accompany his report, but as he died without assigning it a place it is inserted after Part I.]

Appendix "A" is a table of geographical positions giving latitudes, longitudes and altitudes above the gulf of Mexico.

Appendix "B" is a catalogue of plants collected by Mr. Charles Geyer, under the direction of Mr. J. N. Nicollet during his exploration of the region between the Mississippi and Missouri rivers. By Prof. John Torrey, M. D.

Appendix "C" is a list of fossils belonging to the several formations alluded to in the report, arranged according to localities.

A Canoe Voyage up the Minnay Sotor, with an account of the lead and copper deposits of Wisconsin, of the gold region of the Cherokee country, and sketches of popular manners, &c., &c., &c. By G. W. Featherstonhaugh, F. R. S., F. G. S. The preface is dated Dec. 1846. 8vo. Vol. I has pp. 416. Vol. II has pp. 351.

Report of a geological survey of Wisconsin, Iowa and Minnesota, and incidentally of a portion of Nebraska territory. Made under instructions from the U. S. treasury department, by David Dale Owen, U. S. geologist, during the years 1847, 1848, 1849 and 1850. 4to, pp. 638, 72 wood cuts, 27 steel plates, 18 colored maps, stone and copper. Philadelphia, Lippencott, Grambo & Co., 1852.

This volume, embracing a field extending from St. Louis to the British line, and from the west shore of Lake Michigan to the Missouri river, is by far the most valuable contribution to the natural history of the Northwest that had at that time appeared. It throws the first real light, derived from the systematized science of modern times, on the geology and the present fauna and flora of Minnesota. The works of major Long and of Mr. Schoolcraft, mainly narrative or dealing with observations incidentally made on the geology and natural history of the routes they took, embrace many essential facts and able memoirs on special subjects. The report of Dr. Owen is both comprehensive and detailed. He had a numerous corps of able naturalists, and his examinations were sufficiently prolonged to enable him to gather reliable facts enough to lay down correctly the groundwork of a vast extent of scientific research. It is a fortunate thing for geology that at the head of this enterprise was a man so conscientious in his statements, and so careful in his researches. It is no rebuke to geology to say that it has suffered less from its open foes than from the rash generalizations of some of its advocates. Dr. Owen was enabled not only to prove the falsity of some of the statements of mere tourists who had passed through the state, but to establish on correct paleontological evidence the age of most of the bedded rocks of Minnesota, and to throw much light on its topography and soil. It would be expecting too much to look for a pioneer report on so vast a field that should show no errors. Some of these have already been pointed out by more recent observers who confined their examinations to certain parts of the territory on which Dr. Owen reported. Others may appear hereafter.

Dr. Owen's corps consisted of the following gentlemen:

J. G. NORWOOD, assistant geologist.

J. EVANS, B. F. SHUMARD, B. C. MACY, C. WHITTLESEY, A. LITTON, R. OWEN, heads of sub-corps.

G. WARREN, H. PRATTEN, F. B. MEEK, J. BEAL, sub-assistants.

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

Chapter I. Formations of the Upper Mississippi and its tributaries, belonging to the Silurian period.

Chapter II. Formation of Cedar, and part of Lower Iowa river, belonging to the Devonian period.

Chapter III. Carboniferous rocks of southern and western Iowa.

Chapter IV. Formations of the interior of Wisconsin and Minnesota.

Chapter V. Formations of lake Superior.

Chapter VI. Incidental observations on the Missouri river, and on the mauvaises terres (bad lands).

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

Chapter I. Boundaries and topographical notices.

Chapter II. Descriptive catalogue of the rocks referred to in his report.

Chapter III. Narrative of the explorations made in 1847, between La Pointe and St. Louis river; and between Fond du Lac and the falls of St. Anthony, and on the St. Croix river.

Chapter IV. Physical structure and geology of the northwestern and western portions of the valley of lake Superior.

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

Chapter I. General description and geology of the Bad river country, and of that between the Bad river and the Brule; with descriptions and detailed sections of rocks like those which in Michigan are copper-bearing; and accounts of the magnetic iron beds of the Penokie iron range, and of "Iron ridge," in Dodge county, Wisconsin.

Chapter II. Description of the country between the Wisconsin and Menomonie rivers; with a discussion of the general geology, and its relations to other parts of the Northwest.

Chapter III. Red clay and drift of Green bay and Wisconsin.

Chapter IV. Barometrical and thermometrical observations.

Chapter V. Lumbering on the waters of Green bay.

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

Chapter I. Detailed observations on the St. Peter's and its tributaries.

Chapter II. Local sections on the Upper Mississippi.

Chapter III. Local sections on the Wisconsin and Baraboo rivers.

Chapter IV. Observations on Snake, Kettle and Rush rivers.

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

The appendix embraces :—

Article I. Description of new and imperfectly known genera and species of organic remains collected during the geological surveys of Wisconsin, Iowa and Minnesota. By D. D. Owen.

Article II. Descriptions of one new genus and twenty-two new species of *Crinoidea*, from the *Subcarboniferous limestone* of Iowa. By D. D. Owen and B. F. Shumard.

Article III. Summary of the distribution of orders, genera and species in the Northwest.

Article IV. Additional chemical examinations. By D. D. Owen.

Article V. Systematic catalogue of plants of Wisconsin and and Minnesota. By C. C. Parry.

Article VI. Table of stratigraphical and geographical distribution of genera and species in the Northwest.

The Pembina settlement. Letter from the secretary of war transmitting report of Maj. Wood relative to his expedition to Pembina settlement, and the condition of affairs on the northwestern frontier of the territory of Minnesota. Mar. 19, 1850. 8vo. pp. 55. Ex. Doc. No. 51, 31st Cong., 1st session.

Letter from the secretary of war communicating the report of an expedition to the territory of Minnesota. By brevet Capt. Pope, Feb. 5, 1850. Senate, 31st Congress, 1st Sess. Ex. Doc. No. 42, pp. 56. Comprises nine chapters and an appendix containing tables of distances.

Letter from the secretary of war transmitting report of brevet captain J. L. Reno, on the survey, &c., of a road from Mendota to the Big Sioux river. 33rd Congress, 1st session, House of Representatives [97], pp. 12.

Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi river to the Pacific ocean. Made under the direction of the secretary of war in 1853–4, according to acts of Congress of May 3, 1853, May 31, 1854, and August 5, 1854. Thirteen volumes, 4to., Washington, 1856–60.

Single papers.

1. Route near the 47th and 49th parallels of north latitude, vol. I. pp. 39–55.

2. Synopsis of a report of the reconnoissance ofrai lroad route from Puget sound, via Smith's pass to the Mississippi river. By Fred W. Lander, C. E.; vol. II, pp. 45.

Vol. XII. Parts I and II are wholly devoted to the Northern Pacific route, viz:

Part I. Narrative and final report of exploration for a route for Pacific R. R. near the 47th and 49th parallels of north latitude, from St. Paul to Puget sound. By I. I. Stevens, governor of Washington territory, 1855, pp. 358. 41, 2 maps, 1 profile, 70 engravings.

Part II. Botanical report, pp. 7–76, 6 plates; zoological report, pp. 1–399, 76 plates.

Letter, upon the agricultural and mineral resources of the northwestern territories, on the route of the Northern Pacific R. R. By Philip Ritz, Washington, D. C.; 8vo. pp. 8, 1868.

Minnesota. Its place among the states. Being the first annual report of the commissioner of statistics, J. A. Wheelock, for the year ending Jan. 1st, 1860, 8vo. pp. 171.

Minnesota. Its progress and capabilities. Being the second annual report of the commissioner of statistics for the years 1860 and 1861. By J. A. Wheelock. 8vo. pp. 126.

Notes on the geology of some portions of Minnesota from St. Paul to the western part of the state. By James Hall, 1866, 4to. pp. 12. Read June 15, 1866, before the Phil. Soc. of Philadelphia.

Survey of the upper Mississippi river. Letter from the secretary of war in answer to the resolution of the House * * * with general Warren's report of the surveys of the upper Mississippi river and its tributaries, 8vo., pp. 116, Sen. Doc. 39th Cong., 2d Sess. Feb. 15, 1867.

Report of Gen. Warren on the survey of the upper Mississippi river, for the year ending June 30, 1867, 8vo. pp. 6. [Printed in appendix "D," report of the chief of engineers; and as Ex. Doc. No. 1. House of Reps., 40th Cong., 2d Sess., Sept. 14, 1867.]

Report of Gen. Warren on the survey of the upper Mississippi river for the year ending ?. 8vo. pp. 10, 40th Cong., 2d sess. Ex. Doc. 247. April 8, 1868.

Report of Gen. Warren for the year ending June 30, 1868, on the survey of the upper Mississippi river. 8vo. pp. 86. [Printed in appendix "G," report of chief of engineers; and as Ex. Doc. 1, Part II., House of Reps., 40th Cong., 3d sess., Aug. 31, 1868.]

On certain physical features of the upper Mississippi river. By Gen. G. K. Warren. Read by Gen. Warren before the Am. Assoc. Adv. Sci., Aug., 1868, Chicago, Ill. [Printed only in the American Naturalist for November, 1868.]

Geology of southern Minnesota. A series of five papers by W. D. Hurlbut, published in the 4th volume of the Minnesota Teacher, 1871.

Geological rambles in Minnesota. Two papers published in the 4th volume of the Minnesota Teacher, 1871. By J. H. Kloos.

A Cretaceous basin in the Sauk valley, Minnesota. By J. H. Kloos. A paper published in the Am. Journal of Science and Arts, Jan. 1872, dated October, 1871. Condensed and republished in the Minnesota Teacher, vol. 5., 1872.

The first State Legislature met in 1859. Although it was burdened with the legislation incident to the organization of the various institutions of the new State, the subject of a geological survey and its evident importance to the material development of the State, received due attention. A law was passed ordering at once a reprint of portions of the geological report of Wisconsin, by professor Daniels, for the years 1854 and 1858. This republication, printed in 1860, contained Prof. Daniels' "Sketch of the Lead Region," with notes on the evidences of iron ore, which closed with a statement of the "objects of a geological and natural history survey," embracing 34 pp. It also embraced a paper, read before the American Geographical and Statistical Society on the 31st of January, 1856, by Mr. A. S. Hewitt, on the "Statistics and History of the production of iron." pp. 47. Five hundred copies ordered printed.

The second Legislature passed March 10, 1860, a concurrent resolution providing for "Commissioners" to report on the geology of the state, and to submit a plan for a thorough geological survey of the state. The commissioners appointed were Charles L. Anderson and Thomas Clark. These gentlemen submitted separate reports under the date of Jan. 25, 1861, making an octavo pamphlet of 26 pages, of which 2,000 copies were ordered printed. This pamphlet embraces a chapter on the *general geological features of Minnesota*, and one on a *plan for a geological survey*, by Mr. Anderson; also one by Mr. Clark on the *meteorology of the state*, and another on some general topographical and geographical features of the northeastern portion of the state.

The report of the state geologist, Aug. H. Hanchett, M. D., is a pamphlet of 82 pages, 8vo., and is dated New York city, Nov. 13, 1864. It was made in pursuance of executive instructions bearing date July 12, 1864. It contains a short report of ten pages, by Dr. Hanchett, and a valuable report by Mr. Clark on (1) *The physical geography* of the district embraced in that portion of the state bordering on lake Superior. (2) A discussion of the *meteorology of the district.* (3) *A list of the leading plants and trees* of the district. 500 copies printed.

The first report of H. H. Eames, as state geologist, was made in pursuance of an act of the seventh Legislature, and printed in 1866. Two editions of 3,000 copies each were ordered. It is a pamphlet of 23 pages, and pertains specially to "*The metalliferous region bordering on lake Superior.*" It gives the details of personal explorations and the results of chemical assays of ores for the precious metals.

Report of explorations in the mineral regions of Minnesota, during the years 1848, 1859 and 1864; by Col. Chas. Whittlesey. Printed by order of the legislature in 1866, 8vo. pp. 52, close type, with wood-cut illustrations. 3,000 copies ordered.

This, by far the most valuable state document pertaining to the geology and natural history of the state that has yet appeared, embraces short chapters as follows: *General geology; phenomena of the drift period; general elevations in Minnesota; fluctuations in the level of the lakes*; *climate.*

Notes on the valley of the Baragas river.
" " Kawimbash river.
" " Two Islands river.
" " Manedowish river.
" " Baptism river.
" " Palisade river.
" " Beaver river.
" " Low Bush river.
" " Encampment river.
" " French river.
" " Knife river.
" " Sucker river.
" " Henry Schmidt's river.
" " Hollow Rock river.
" " St. Louis river.
" " Rainy Lake river.

Notes on the shores of the Esquamega, Vermilion and Crane lakes and on the cost of mining copper.

Geological reconnoissance of the northern, middle and other counties of Minnesota. By Henry H. Eames, state geologist, printed in 1866, 8vo., 58 pp. This pamphlet comprises the second, and last, report of Mr. Eames. It embraces:

A brief outline of the different formations or systems of rocks that form the crust of the earth; remarks on the igneous, the coal-bearing, and the sandstone and limestone rocks of the state; also on peat; on mineral and fissure veins; on agricultural chemistry; on a geological reconnoissance "in detail" of the counties of St. Louis, Lake, Itasca, Cass, Todd, Otter Tail, Douglas, Stearns, Morrison, Benton, Sherburne, Redwood, Cottonwood, Ramsey and Washington; together with results of assays and thermometrical and barometrical observations in the months of June, July and August.

Copper-bearing veins having been discovered in the valley of the Kettle river, and at Taylor's Falls, in the valley of the St. Croix river, the Legislature passed, Mar. 2, 1865, an act to aid in their investigation. The report of Mr. N. C. D. Taylor, the following year, consists of only two pages, incorporating Mr. James Hall's estimate of the copper prospects of that district. 500 copies printed.

Indications of brine having been discovered at Belle Plaine, in

Scott county, the Legislature passed, 28th day of February, 1870, an act appropriating land in aid of a boring for the purpose of developing the salt, should any exist. In 1871 another similar appropriation was made by the legislature, conditional on a favorable report by a competent geologist, to be appointed by the governor. Prof. A. Winchell, of Ann Arbor, Mich., having been so appointed, made the required examination; and his report, dated June 17, 1871, was printed by order of the Senate. It is an 8vo. pamphlet of 16 pages. Notwithstanding the unfavorable opinion of the geologist, the Legislature made the further appropriation, Feb. 29, 1872, of six other sections of "state salt lands," for the further sinking of the well, making eighteen sections or eleven thousand three hundred and twenty acres of land in all. No brine in workable quantities was obtained.

The same legislature passed, March 1st, 1872, the present comprehensive law placing the geological and natural history survey under the direction of the board of regents of the state university. This law reads as follows:

GENERAL LAWS OF MINNESOTA, 1872, CHAPTER XXX.

An Act to provide for a geological and natural history survey of the state and to entrust the same to the University of Minnesota.

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

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

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

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

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

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

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

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

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

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

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

Approved March 1, 1872.

II.

GENERAL PRINCIPLES.

The science of geology is based on those general principles which, resulting from the accumulated observations of its advocates during the last half century, have become to the geologist himself the merest alphabet to which he seldom recurs in the prosecution of his more advanced investigations. The following brief statement of those principles is here given for the benefit of those persons who are not specially acquainted with the science, but yet are fascinated, perhaps, by its wonderful progress, and its success in utilizing its discoveries to the general good, and wish to comprehend at a glance the sub-structure on which it is built. It is not an occult science. Its data are open to the investigation of the commonest observer. It is founded on such simple things as the running of brooks, the blowing of winds, the rippling of waves, the shining of the sun, the cooling of heated matter, the growth of vegetation and the death of animals that live on land and in the sea. These everyday operations have given to the earth its external aspects, and have left their history in the rocks. The constancy of the present laws of nature through the lapse of the geological ages, is a pre-requisite to the existence of the science. Time, as the word is commonly understood, must be immensely lengthened out. These two postulates granted—*that time is long*, and *that the physical laws of the universe have been constant throughout time*—and nothing more is needed for the foundation of the science. The geologist, with these postulates, and by the aid of a knowledge of the physical laws of nature derived from a comprehensive examination of the earth in the light of all the sciences, may read in the rocks the grand changes the earth has undergone since "the beginning." The failure to comprehend the science of geology is very often attributable to a restricted acquaintance with the principles of other sciences which it involves; for however simple the first process in which it begins, those processes are,

CHART OF GEOLOGICAL NOMENCLATURE.

Intended to express the relation of Minnesota to the great Geological Series of the Earth, and the probable equivalency of some of the names the formations have received in the various States and in Europe.

BY N. H. WINCHELL.

ERAS.		AGES. (*Systems.*)		PERIODS. (*Groups.*)	EPOCHS. (*Formations.*)	Sub-Epochs—(*strata.*)					
						NORTH AMERICA.	MINNESOTA.	IOWA.	ILLINOIS.	TENNESSEE.	EUROPE.
CÆNOZOIC.	Age of Angiosperms and Palms.	AGE OF MAMMALS.		QUATERNARY.	HUMAN.	Bluff. Alluvium. Peat. Bog Ore. Cave deposits.	Bluff. Alluvium. Peat. Bog Ore. Terraces.	Alluvium. Bluff.	Peat. Loess. Alluvium. Bog Ore. Terraces.	Alluvium and Bluff Group.	Loess. Peat. Cave deposits.
					GLACIAL.	Boulders. Gravel. Moraines. Erie Clay. Glacial Drift.	Boulders. Gravel. Moraines. Hardpan Clay, or Glacial Drift.	Gravel Ridges. Moraines. Boulders. Glacial Clay.	Pebbles. Boulders. Moraines. Glacial Clays.	Wanting.	Gravel Ridges. Moraines. Glacial Drift.
				TERTIARY.	UPPER TERTIARY.	Sumter Beds.	?	Wanting.	Wanting.	Bluff Lignite.	Newer Pliocene. Older Pliocene.
					MIDDLE TERTIARY.	Yorktown Beds.	?	Wanting.	Wanting.	La Grange Group. (Orange sand.)	Miocene.
					LOWER TERTIARY.	Vicksburg. Jackson. Claiborne.	?	Wanting.	Eocene.	Porter Creek Group.	Upper Eocene. Middle Eocene. Lower Eocene.
MESOZOIC.		AGE OF REPTILES		CRETACEOUS.	UPPER CRETACEOUS.	Fox Hills. Fort Pierre.	Wanting?	Wanting.	Wanting.	Ripley.	Maestricht Beds. White Chalk.
	Age of Cycads.				MIDDLE AND LOWER CRETACEOUS.	Niobrara. Benton. Dakota. Wanting? Wanting?	Benton. Dakota? Wanting. Wanting.	Inoceramus Beds. Woodbury Sandstone and Shales Nishnabotany Sandstone. Wanting. Wanting.	Wanting.	Green Sand. Coffee Sand. Wanting. Wanting.	Chalk Marl. Upper Green Sand. Gault. Lower Green Sand.
					WEALDEN.	Wanting.	Wanting.	Wanting.	Wanting.	Wanting.	Wealden.
				JURASSIC.	OOLITIC. LIASSIC.	Not yet subdivided in N. America, Nor separated from the *Triassic*.	Wanting.	Wanting.	Wanting.	Wanting.	Oolite. Lias.
				TRIASSIC.	NEW RED SANDSTONE.	Not yet subdivided in N. America. Occurs in New Mexico, Colorado and Dakota.	Wanting.	Wanting.	Wanting.	Wanting.	Keuper. Muschelkalk. Bunter Sandstein.
PALÆOZOIC.	Age of Acrogens.	CARBONIFEROUS or AGE OF COAL PLANTS and AMPHIBIANS.		PERMIAN.	PERMIAN.	Not certainly identified in N. Am., nor separated from *Coal Measures*.	Wanting.	Wanting.	Wanting.	Wanting.	Stinkstein. Rauchwacke. Zechstein. Rothe Todt-leigende.
				COAL MEASURES.	COAL MEASURES.	Upper Coal Measures. Lower Coal Measures.	Wanting?	Upper Coal Measures. Middle Coal Measures. Lower Coal Measures.	Upper Coal Measures. Lower Coal Measures.	Coal Measures. Conglomerate. False Coal Measures.	Upper Coal Measures. Lower Coal Measures.
				CARB. CONGLOMERATE.	MILLSTONE GRIT.	Parma Conglomerate.	Wanting?	?	Millstone Grit.	?	Millstone Grit.
				SUB-CARBONIFEROUS.	MISSISSIPPI.	Chester Limestone. St. Louis Limestone. Keokuk Limestone. Burlington Limestone.	?	St. Louis Limestone. Keokuk Limestone. Burlington Limestone.	Chester Limestone. St. Louis Limestone. Keokuk Limestone. Burlington Limestone.	Monntain Limestone.	Mountain Limestone.
					MARSHALL.	Marshall Sandstone.	?	Kinderhook.	Kinderhook.	Siliceous.	Old Red Sandstone.
		DEVONIAN or AGE OF FISHES.		HAMILTON.	HAMILTON.	Huron Shales. Hamilton Limestone	Huron Shales. Hamilton Limestone.	Hamilton Limestone and Shales.	Genesee Division. Hamilton Beds.	Black Shale. Wanting.	Cypridiner schiefer. Orthoceras schiefer. Spiriferen sandstein.
				UPPER HELDERBERG.	CORNIFEROUS.	Corniferous Limestone. Onondaga Limestone.	Corniferous Limestone? Wanting.	Wanting.	Corniferous Limestone. Onondaga Limestone.	Wanting.	
					ORISKANY.	Schoharie Grit. Cauda-Galli Grit. Oriskany Sandstone.	Wanting.	Wanting.	Upper Oriskany. Lower Oriskany.	Wanttng.	
	Age of Algæ.	SILURIAN, or AGE OF MOLLUSKS.	Upper Silurian.	LOWER HELDERBERG.	HELDERBERG.	Up. Pentamerus Limestone. Encrinal Limestone. Delthyris Shaly Limestone. Low. Pentamerus Limestone. Water Limestone.	?	Wanting.	Lower Helderberg Group.	Lower Helderberg.	Ludlow Group.
				SALINA.	SALINA.	Onondaga Salt Group.	?	Wanting.	Wanting.	Wanting.	
				NIAGARA.	NIAGARA.	Guelph Limestone. Niagara Limestone. Niagara Shale.	Niagara Limestone.	Niagara Limestone.	Niagara Group.	Meniscus Limestone.	Wenlock Limestone. Wenlock Shales.
					CLINTON.	Clinton Group.	Wanting.	Wanting.	Wanting.	Dyestone Group.	Upper Llandovery.
					MEDINA.	Medina Sandstone.	Wanting.	Wanting.	Wanting.	White Oak Mountain Sandstones	Upper Caradoc Sandstone.
					ONEIDA.	Oneida Conglomerate.	Wanting.	Wanting.	Wanting.	Clinch Mountain Sandstones.	Coniston Grits. Lower Llandovery.
			Lower Silurian.	CINCINNATI.	CINCINNATI.	Cincinnati Group.	Maquoketa Shales.	Maquoketa Shales.	Cincinnati Group.	Nashville.	Caradoc, or Bala Group.
					TRENTON.	Galena Limestone. Trenton Limestone. Black River Limestone. Bird's Eye Limestone. Chazy Limestone.	Galena Limestone. Trenton Limestone and Shales.	Galena Limestone. Trenton Limestone.	Galena Limestone. Trenton Limestone.	Trenton.	Upper Llandeilo.
				PRIMORDIAL.	QUEBEC.	St. Peter Sandstone. Low. Magnesian Limestone.	St. Peter Sandstone. Low. Magnesian Limestone.	St. Peter Sandstone. Low. Magnesian Limestone.	St. Peter Division. Calciferous Division.	Knox Group.	Lower Llandeilo.
					POTSDAM.	Potsdam Sandstone.	St. Croix Sandstone. Potsdam Sandstone.	Potsdam Sandstone. Sioux Quartzite.	Not exposed.	Chilhowee Sandstone. Ocoee Conglomerate.	Lingula Flags.
EOZOIC.		AGE OF WATER AND FIRE.		EOZOIC.	METAMORPHIC.	Huronian System. Laurentian System.	Huronian System. Laurentian System	Not exposed. Not exposed.	Not exposed.	Metamorphic.	Cambrian. Fundamental Gneiss.
AZOIC.		AGE OF FIRE.		AZOIC.	IGNEOUS.	Primary Granites and Syenites.		Not exposed.	Not exposed.	Azoic.	Primary Granites and Syenites.

when duly amplified, very often the starting points of other sciences which first grew up, expanded and usurped the whole field of scientific thought. It is a simple thing to observe the growth of a plant from the seed—it is another to know the relations of that plant to others by which it may be surrounded, and by botanical classification to define its nature and structure. It is an easy thing to see the effect of the sun's rays on the vegetation of the earth, and to comprehend the cause for the change of the seasons, as well as to note the alternations of day and night, but the versed astronomer only can realize the full force of the great laws involved in these changes, and indicate their effect on the earth when acting through the lapse of ages. It is an easy thing to note the freezing up of the streams, and their bounding violence on being released in the spring; to see the destruction of forests by tempests and by fires; to observe the blowing of sands and the dashing of waves; but, although these things are very simple, the science of meteorology is too abstruse to be even fairly appreciated by the common mind. The rusting of iron, the decaying of wood, the cementation of gravel by percolating water, the demolition of rocky outcrops and their conversion into soil by the solvent action of the moisture of the air and of overflowing streams, are things of common and easy observation, but the science of chemistry, in the light of which they alone can be adequately understood, is the outgrowth of the laws of occult affinities between the particles of matter, the full power of which it is impossible to estimate, and much more to express. Thus all the sciences, and notably that of zoology, have yielded up to the geologist their keys to the *arcana* of nature, and have assisted in interpreting the otherwise unintelligible records which lie in the rocks of the earth. The geologist must not be restricted to the mere inspection of the rocks, for he has to question the botanist, the chemist, the zoologist, the astronomer, and the general physicist. These are in a broad sense his aids. By his generalizations the society of the sciences is made evident, and some of their varied bearings one upon the other are adjusted, and expressed in their full significance. In return the science of geology reflects light on the other sciences. It gives greater value to the labors of the mineralogist, guides the miner in his explorations, opens fields for investigation to the chemist, shows the botanist and the zoologist thousands of unnamed and unclassified species, propounds to the astronomer the *glacial epoch* for explanation, and explains to the agriculturist the true basis of the difference in soils.

The rocks which are classed, in general, as *Granitic and Metamorphic* are those which appeared first above the waters of the universal ocean, or have since been upheaved by internal forces from the heated mass within the crust. In the former case they have been dry land since they first appeared above the ocean, and have supplied largely the materials of the later, overlying, sedimentary formations. In the latter case they have been protruded upward through the sedimentary rocks, tilting them in various directions and so fracturing their bedding as to disclose their contents to the geologist. Round the bases of these early granitic areas the currents of the ocean, driven by the rising and falling of the tides, by the rotary motion of the earth, and by the unequal distribution of the heat of the sun, flowed with an unceasing activity, and the tumultuous waters beat with a violence that probably is never witnessed in modern days. They were thus gradually torn down, and their *debris* was spread over the uneven ocean bed in horizontal layers according to the direction and force of the currents. In that manner the primordial, or *Potsdam*, sandstone was formed. It hence everywhere lies at the base of the evidently sedimentary rocks. *It was deposited in the bed of the ocean.* If it now appears as dry land, it is because the ocean's bed has risen above the water level. The history which may be read from it is that of the ocean's bed. It tells of deep waters and shoal waters, of muddy bottoms and stony bottoms, of warm, drying sunshine and gentle winds, of violent currents and stormy seas, of impure waters heated by frequent ejections of sulphurous gases from below the thin crust, and of chemical reactions that to-day are the familiar steps of the laboratory. It reveals the earliest of created beings. They lived in the ocean. Their remains are dug out of the hardened sediment by the geologist, and he calls them *fossils*.

The changes that continued to go on in the conditions of the earth, owing to the cooling and the shrinking of the interior, effected various changes in the relative prevalence and positions of the land and water. Additional dry land appeared, thus bringing from the bed of the ocean a part of the freshly formed *Potsdam sandstone*. A period of repose sufficed for the deposit of the calcareous material of the *Lower Magnesian*, which next overlies the

Potsdam. This, however, was not spread over the earlier sandstone, except where the latter still extended below the ocean. It was accompanied with new and more abundant forms of animal life, so that it may be certainly distinguished from the foregoing and from the succeeding formations. The conditions of the oceanic waters were such that chemical reactions resulted in the precipitation of the carbonates of lime and magnesia. Silica, also, seems to have been in solution, and to have shared in the incessant changes in the surrounding affinities. These three substances, with some iron and traces of alumina and manganese, make up the mass of the *Lower Magnesian limestone.* The prevalence of silica in the form of sand gives it also the name of *Calciferous sandrock.* The chert, in its lower portions, is also largely composed of siliceous material.

To the *Lower Magnesian* succeeds the *St. Peter sandstone.* That in turn is followed in ascending order by the *Trenton* shales and limestones. Thus, through the whole thickness of the stratified rocks of the earth, each formation marks an epoch in the history of the ocean's bed. The dry land constantly increased in area, gradually bringing to the surface the sediments of the latest preceding epoch. Hence the areas of the various formations are arranged over the face of the country in broad belts in consecutive order, revealing the chronological system as well as the territorial accessions with which the continent grew.

The rocks thus deposited in the bottom of the ocean, and subsequently raised to the level of dry land, are called stratified or aqueous, in distinction from the earliest, or igneous, which show no arrangement into beds. The lowest sedimentary rocks are locally so changed by contact with escaping gases and molten material as to essentially alter their usual character. The limestones have been converted to saccharoidal marbles, the sandstones to quartzytes, the clays and shales to slates, while many of the earliest are also entirely changed by chemical transformations among their elements, resulting from the same grand agencies, to schists and even gneiss, mica and hornblende slate, that can hardly be distinguished from some of the igneous rocks themselves. The geologists of Canada even report granite and syenite, pertaining to the Laurentian, as metamorphic sedimentary rocks. (See Geology of Canada, 1863, p. 23)

It is evident that when the true succession of the rocks of the earth has once been made out by the study of their permanent characters, the geologist may enter any country however remote or unknown and enter fearlessly on the work of deciphering the age of its rocks, depending solely on the universality of the grand principles of his science.

A complete geological history of the past can be read from the rocks of the earth only by the study of causes and effects operating in the present. In order to that a perfect acquaintance with the various departments of natural science becomes essential. The laws of physics, chemistry and astronomy have with their multiform ramifications played as important parts in the early geological ages as they now play in the transactions of every day. The natural forces concerned in vegetable growth, distribution and decay, are involved in the deposition and preservation of the coal rocks in their proper horizon. Hence botany with its allied subject, meteorology, is embraced in a perfect knowledge of geology. The identification of the rocks of the great *Coal Period*, as distinguished from others containing coal, is based on a botanical law, a distinction in plants. As to zoology, that subordinate department derives much of its significance and value from the uses it subserves to geology. Its nomenclature, and its principles have been wonderfully modified and extended by the discovery and proper classification of the animal forms embraced in the strata of the earth's crust, while the science of zoology furnishes to the geologist the only reliable key to the establishment of the age of any of the stratified rocks of the earth. All characters, except those known as paleontological, fail of permanence, and cannot be depended on at distant points. A geological survey cannot be conducted, much less completed, without a full examination and delineation of the animals and plants that are preserved in the rocks surveyed. The dead past far outnumbers the living present. It is with the greatest propriety that botanical and zoological departments are usually attached to the geological surveys undertaken by the various states of the union, intended to embrace also the enumeration of living species.

The subjoined chart of geological nomenclature is intended to convey an idea of the relation of Minnesota to the great geological series of the earth, and to express the probable equivalency of some of the names which the formations have received in different states and in Europe.

III.

THE SURFACE CONTOUR OF THE STATE.

The intimate relation subsisting between the geology and the topography of the state is more evident than in some of the other states of the union. The causes which determine the location of the great continental water-shed are those which determined the existence of the Laurentian and lake Superior ranges of igneous and metamorphic rocks. The area of these rocks in Minnesota, as well as in Wisconsin and Michigan, includes some of the sources of the great river systems of the Northwest and of the continent. From this area, since pre-Silurian times, streams have run in all directions toward the ocean. Within this area, in the state of Minnesota, are the headwaters of the St. Lawrence system of drainage, which enters the Atlantic ocean toward the east; those of the Mississippi which enters the gulf of Mexico toward the south, and those of the Red river of the North, which, taking an opposite course, finds the ocean level toward the north, through Hudson's bay, in British America. This watershed consists not in the form of a definite and abrupt ridge. The oldest rocks are, on the contrary, spread out over a very extensive region of flat and often prairie country. Occasional knobs of these rocks protrude through the drift, or they show extensive tracts of denuded surface, rising but few feet above the surrounding level.

While in general these rocks form the principal watershed, in some parts of the state the later sedimentary rocks rise much higher and give origin to numerous streams which reach the main valleys at considerable distance from the granite areas. Such an elevated area of sedimentary rocks occurs in southern Minnesota, forming there the summit of a second water-shed. Freeborn, Faribault, Martin and Cottonwood counties are probably the most elevated in the state, the altitude there reaching nearly 1,600 feet above the ocean. How much of this extraordinary elevation is due to a moraine-like accumulation of drift, it is impossible to say, but probably the average thickness of that deposit would not fall short of one hundred feet. Streams from this area enter Iowa toward the south, some also running northward and joining the Minnesota river. The course of the surface drainage is in this case dependent very little on the character of the underlying rock. But where the drift is lighter, the direction of subordinate streams is often determined by the bearing of the sedimentary rocks. A stream is most likely to be located in the depression caused by the erosion or other destruction of the outcropping edge of a soft or friable rock, the more persistent formation adjoining it, above and below, forming the divides between it and other streams. Other causes, however, principally those superinduced by undulations in the strata over long distances, so as to cause them to leave the direction of the principal or tributary valleys, and the variations of level brought about by the unequal deposition of the drift during the prevalence of the ice of the glacial epoch, have very generally masked the effect of unequal erosion of the strata on the direction of surface drainage. One remarkable instance of the effect of geological causes in determining the location of valleys, and hence of drainage streams, through variations in the hardness of the underlying rock, may be mentioned. The Mississippi river, from a short distance below the mouth of the St. Croix to the southern boundary line of the state, and to the mouth of the Wisconsin river which joins it at Prairie du Chien from the east, flows through a tract of country in which the drift forces acted with far less violence than in other tracts further to the east or west, or even further to the south. Whatever may be the cause of the comparative exemption of this district from the prevalence of the drift in that latitude in other parts of the United States, it is a fact so observable that Mr. J. D. Whitney, some years ago, denominated it a "driftless region," where it enters the state of Iowa. Hence it is here, if anywhere, that the character of the underlying rock would influence the direction of drainage. Throughout this distance the bluffs of the Mississippi are specially elevated and rocky. The river has not infrequently cut into the formations, with which it comes in contact, a perpendicular depth of over six hundred feet, excavating a channel often of four or five, and sometimes of nearly ten miles in width. Sometimes old channels that have been abandoned lie along one side, or both, and are filled with water only during the freshet season. Throughout this distance it follows exactly the strike of the Lower Silurian rocks. The *St. Peter sandstone*, on which it enters at St. Anthony's falls, is underlain by a very enduring rock known as the *Lower Magnesian limestone*. That, in order, is also underlain by the more erosible sandstones of the St. Croix valley. Hence we have an enduring limestone rock intercalated between two easily destructible sandstones. Yet it is a remarkable fact that this limestone, the strike of which would ordinarily form, under the operation of natural causes, a ridge or divide turning the surface waters in opposite directions into the valleys of the sandstone areas, forms the summits of the river bluffs nearly the whole distance. The river has not only cut its channel through the first sandstone, a thickness of over one hundred feet, and the *Lower Magnesian limestone*, a thickness of about three huudred feet, but also into the lower sandstone to the depth of two or three hundred feet, on which it is now running. At the present time the river lies in the strike of the more enduring limestone, the overlying sandstone having retreated from the immediate river banks. Its agency in locating the river is only manifest by the existence to the present day, of isolated outliers of it, in the form of the well known "Trenton mounds," on the eastern side of the river, its present line of outcrop running some miles further west. While the river has been slowly wearing its way into the *Lower Magnesian limestone*, and through it into the *St. Croix sandstone*, on the line where the overlying *St. Peter sandstone* predetermined it, the *St. Peter* itself has almost entirely disappeared from the river, and been lost under the attacks of the elements, its substance having been spread over the high prairies, or on the low bottom lands, as the principal ingredient of the rich loams which characterize that portion of Minnesota. Hence we also have the singular phenomenon of a slight descent in the surface of the country westward from the tops of the bluffs of the Mississippi, in southern Minnesota, while the streams tributary to it actually reach it by flowing to the east. This can be explained only on the supposition that the *St. Peter sandstone* formerly had its outcrop about where the Mississippi now runs, forming then there, as it forms now along its line of junction with the *Lower Magnesian limestone*, a marked depression in the general surface, but that in the lapse of time its line of outcrop, and necessarily that of all overlying rocks, was driven, by the operation of destructive agencies, further to the west, leaving the next lower formation to round out the bluffs along the river. The tributary streams, having once entered the Mississippi from the west, would keep their beds also eroded down to a level with that river, and would continue to enter that stream by passing in like manner between high and rocky banks, which would attain their greatest hight just at their union with the bluffs of the Mississippi. At Prairie du Chien the direction of the strike of the *St. Peter sandstone*, and of all the Silurian rocks changes, and passes away from the Mississippi valley toward the east. But the Wisconsin river bears the same relation to the *St. Peter sandstone*, running along its ancient line of bearing, its main outcropping edge being driven away from the immediate valley toward the south, while outliers on the northern side attest its former prevalence intact over the whole valley.

Enough has been said to show the importance of a knowledge of elevations above a common level at all ascertained points throughout the state. Efforts have been made to obtain the hypsometrical data of the state complete up to the present time, so far as indicated by railroad or other surveys. The following list of elevations is the result. To this list additions will be made from time to time. The figures show the altitudes of the points named above lake Superior, and above the ocean. When not otherwise mentioned, the points given are on the grade of the road.

On the line of the Lake Superior & Mississippi R. R.

FURNISHED BY A. J. HILL.

Miles from Duluth.		Feet above lake Superior.	Feet above the ocean.
0	Surface of lake Superior at Duluth in 1870	0	602
0	Duluth..............................	6	608
21	Thomson. Dalles of the St. Louis river.........	430	1032
33	Highest point on entire line, both of grade and natural surface..............................	569	1171
45	Moose Lake depot..............................	462	1064
60	Kettle River depot. (Ground a little to the north and south is 15 to 20 feet higher).............	428	1030
78	Hinckley, at Grindstone river	429	1031
	Lowest place between Hinckley and next summit, grade..............................	408	1010
80	Summit, grade..............................	418	1020
86	Summit, (20 feet higher than at ½ mile to the N. or S.), grade..............................	388	990
90	Pine City, at Snake river..............................	347	949
	Two and a half miles south of Snake river, at summit, grade..............................	381	983
101	Rush City, at creek..............................	314	916
	Descending gradually from Rush City to Goose creek		
	Goose creek, grade..............................	289	891
	Between Goose creek and N. Branch.	318	920
113	N. Branch depot..............................	292	894
	Between N. Branch and Wyoming..............	309	911
125	Wyoming, at the river, grade..............................	291	893
125	Wyoming depot..............................	294	896
129	Forest Lake depot..............................	307	909
132	Summit between Forest Lake and Rice creek.....	352	954
133½	Rice creek, grade..............................	319	921
	Country generally level for five miles south of Rice creek.		
137½	Centerville depot..............................	329	931
142½	White Bear, junction to Stillwater..............	332	934
145¼	Summit between White Bear lake and St. Paul (8 feet cut), grade..............................	362	964
151	Between Phalen's lake and St. Paul.............	273	875
154	Lowest known water in Miss. R. at St. Paul.............. } Extreme range 19 feet.	81	683
154	Highest known water in Miss. R. at St. Paul.............. }	100	702

On the line of the Northern Pacific R. R.

FURNISHED BY W. MILNOR ROBERTS, CHIEF ENGINEER.

Miles from Duluth.		Above lake Superior.	Above the ocean.
0	Duluth (level of L. Superior) about	0	602
24	Junction (natural ground)	479	1081
24.2	Junction (grade)	480	1082
27	Otter creek (bed of creek)	526	1128
34	(natural ground)	733	1335
34.1	Norman (grade)	722	1324
41.7	Kettle river (bed of the river)	685	1287
44.7	(natural ground)	729	1331
46	Island lake (grade)	705	1307
51.7	Tamarack river (bed of the river)	685	1287
51.9	(natural ground)	709	1311
55.2	(natural ground)	678	1280
58.1	Sicottes (grade)	665	1267
62.2	Hay river (bed of the river)	622	1224
62.8	(natural ground)	638	1240
65.4	Sandy river (bed of the river)	613	1215
72.3	(natural ground)	612	1214
73.8	(natural ground)	660	1262
76	Kimberly (grade)	631	1233
76.5	Rice river (bed of the river)	603	1205
80.8	(natural ground)	648	1250
83.5	Sisabagama creek (bed of creek)	600	1202
85.3	(natural surface)	635	1237
87.1	Aitkin (grade)	602	1204
87.7	Mud river (bed of the river)	586	1188
90.2	(natural ground)	618	1220
91.8	Cedar river (bed of the river)	593	1195
97.5	(natural surface)	699	1301
98.2	Deerwood (grade)	666	1268
103.6	(natural surface)	697	1299
115	Brainerd (grade)	604	1206
115.5	Mississippi river (bed of river)	538	1140
	Banks of the Mississippi river (grade)	604	1206
120.6	Frenchman's (grade)	599	1201
120.9	(natural ground)	606	1208
122.5	Gull river (bed of the river)	561	1163
124.7	(natural ground)	604	1206
127.6	Pillager creek (bed of creek)	566	1168
128.2	Pillager (grade)	580	1182
135.5	(natural ground)	622	1224
136.5	Crow Wing river (bed of the river)	597	1199
137.1	Motley (grade)	620	1222
141.5	(natural ground)	650	1252
143.3	Hayden's branch (bed of creek)	624	1226
150.9	(natural ground)	742	1344
151.3	Aldrich (grade)	726	1328
151.5	Partridge river (bed of river)	704	1306
155.3	(natural ground)	747	1349
156.5	Wing river (bed of river)	712	1314
158.2	(natural ground)	757	1359

On the line of the Northern Pacific R. R.—continued.

Miles from Duluth.		Above lake Superior.	Above the ocean.
161.3	Union creek (bed of creek)	720	1322
161.9	Wadena (grade)	749	1351
164.1	(natural ground)	754	1356
166.4	Leaf river (bed of river)	707	1309
174.8	New York Mills (grade)	809	1411
177.2	(natural ground)	831	1433
183.4	Otter Tail river (bed of river)	718	1320
185.5	Perham (grade)	766	1368
190.7	(natural ground)	779	1381
192.6	Otter Tail river (bed of the river)	735	1337
195.4	Hobart (grade)	784	1386
196.1	(natural ground)	802	1404
196.2	Otter Tail river (bed of the river)	753	1355
201.4	(natural ground)	820	1422
205.8	Pelican river (bed of the river)	737	1339
206.6	Detroit (grade)	762	1364
210.7	(natural ground)	806	1408
210.9	Oak Lake (grade)	767	1369
213.6	Audubon (grade)	708	1310
214.7	(natural ground)	667	1269
217	(natural ground)	748	1350
219.2	Lake Park (grade)	733	1335
224.2	Hay creek (bed of crrek)	600	1202
226.6	Hay creek (bed of creek)	567	1169
227.4	Buffalo river (bed of river)	550	1152
230.1	Buffalo river (bed of river)	532	1134
230.4	Hawley (grade)	550	1152
231.4	(natural ground)	595	1197
234.9	Muskoda (grade)	483	1085
238.3	Buffalo river (bed of river)	338	940
242	Red river flats (natural ground)	378	980
243.2	Glyndon (grade)	323	925
252	Moorhead (grade)	304	906
252.2	Red river (bed of river)	257	859
	Red river banks (natural ground)	302	904

On the line of the St. Paul & Sioux City and Sioux City & St. Paul R. R.'s.

FURNISHED BY HON. E. F. DRAKE.

Miles from St. Paul.		Above lake Superior	Above the ocean.
47	Belle Plaine	123	725
52	Blakely	126	728
58	East Henderson	132	734
63	Le Sueur	151	753
69	Ottawa	188	790
77	Kasota	198	800
86	Mankato	189	791
90	South Bend	206	808
100	Lake Crystal	392	994
110	Madelia	419	1021
121	St. James	471	1073
130	Butterfield	582	1184
137	Mountain Lake	698	1300
143	Bingham Lake	818	1420
148	Windom	751	1353
154	Wilder	846	1448
160	Heron Lake	815	1417
170	Hersey	883	1485
178	Worthington	980	1582
188	Bigelow	1029	1631
196	Sibley	907	1509
245	Le Mars	619	1221

St. Paul & Pacific R. R.—Main line.

FROM THE RECORDS IN THE OFFICE OF THE CHIEF ENGINEER, C. A. F. MORRIS. BY N. H. W.

Miles from St. Paul.		Above lake Superior	Above the ocean.
0	Low water in Mississippi river at St. Paul	81	683
0	St. Paul depot	102	704
0	Base of the capitol, St. Paul	190	792
0	Bluffs back of the capitol—		
	Head of Robert street	308	911
	Summit avenue bluff	318	920
5	Summit between St. Paul and St. Anthony (3 feet cut)	328	930
9.5	Junction at St. Anthony	240	842

S Paul & Pacific R R.—Main line—continued.

Miles from St. Paul.		Above lake Superior	Above the ocean.
9.5	Mississippi R. (low water) at Nicollet island, St. Anthony	198	800
10.5	Minneapolis station	232	834
	Mississippi R. (low water) half mile below St. Anthony falls	118	720
17	Self's lake (water)	253	855
24	Wayzata station	334	936
25	Lake Minnetonka (water)	326	928
28	Long Lake station	352	954
40	Crow River crossing (track)	326	928
40	Delano	326	928
48½	Waverly station	397	999
51½	Twelve Mile creek (track)	398	1000
54	Howard lake	408	1010
57	Smith lake	452	1054
59		448	1050
60	Sucker creek (track)	415	1017
60	Sucker creek (water)	392	994
61	Cokato	448	1050
64	Collinwood creek (track)	425	1027
67½		519	1121
68.5	Level of marsh	490	1092
69.5		520	1122
72	Darwin (Big prairie)	530	1132
79	Litchfield station	527	1129
86	Swede Grove station	590	1192
89	Anderson's hill (cut 15 feet)	614	1216
91	Summit (Atwater)	609	1211
92	Cut 10½ feet	639	1241
95.5	Highest point on line (cut 3 feet)	667	1269
98	Very rolling surface to Kandiyohi station	620	1222
105	Willmar station (at Foot lake)	527	1129
110.5	St. John's	519	1121
118	Nearly level to Kerkhoven	506	1108
127	Smooth surface to De Graff station	459	1061
132	Sharp summit (cut 16 feet)	464	1066
134	Gradual descent, smooth surface to Benson station	445	1047
135.5	Chippewa river (bridge track)	433	1035
135.5	Chippewa river (water)	418	1020
140	Gradual ascent, smooth surface, to Clontarf station	442	1044
147	Gradual ascent, smooth surface, to 147's mile post	472	1074
150	Hancock station	553	1155
151.5	Summit	570	1172
155.5	Pomme de Terre river (track)	476	1078
155.5	Pomme de Terre river (water)	464	1066
159	Morris station	527	1129
161	Summit (161's mile post)	554	1156
167.5	Smooth surface to Donnelly station	522	1124
178	Gradual descent, smooth surface, to Herman station	468	1070

St. Paul & Pacific R. R.—Main line—continued.

Miles from St. Paul.		Above lake Superior.	Above the ocean.
184.5	Smooth surface to Mustinka creek	424	1026
185.5	Smooth surface to Gorton	420	1022
194.5	Smooth surface to Tintah	393	995
201	Smooth surface to Rabbit run	380	982
202	Smooth surface to Campbell station	380	982
209	Smooth surface to Doran station	369	971
217	Smooth surface to Breckenridge station	357	59

St. Paul, Stillwater & Taylor's Falls R. R.

COPIED FROM PROFILE IN THE OFFICE OF THE CHIEF ENGINEER, J. S. SEWELL, BY N. H. W.

Miles from St. Paul.		Above lake Superior.	Above the ocean.
0	St. Paul. Low water in Mississippi river	81	683
0	St. Paul. High water in Mississippi river	100	702
1.5	Junction with St. Paul & Pacific R. R.	172	774
	Crossing of L. S. and M. R. R., Phalen's creek (track)	227	829
	Grade of L. S. and M. R. R. here is 20 feet lower	207	809
2	Phalen's creek (bottom) third crossing	201	803
3	Broken surface to second crossing of Phalen's creek (track)	251	853
3	Phalen's creek, second crossing (bottom)	236	838
3.5	Broken surface to first crossing of Phalen's creek (track)	269	871
3.5	First crossing of Phalen's creek (bottom)	251	853
4.5	Broken surface to creek at Ames' farm (track)	321	923
4.5	Creek at Ames' farm (bottom)	290	892
6	Broken ascent to beginning of descent to the Mississippi river (cut 15 feet)	386	988
6.5	Broken surface to tamarack swamp (track)	376	978
6.5	Tamarack swamp (natural surface)	371	973
8	Summit one mile west of Oakdale station (cut 10 feet)	406	1008
9	Oakdale station	377	979
12	Broken surface to the level of Lower Bass lake	284	886
12	Level of Upper Bass lake	298	900
12	Lake Elmo station	331	933
13	Nearly level and smooth surface to road on east line of Oakdale	321	923

St. Paul, Stillwater & Taylor's Falls R. R.—continued.

Miles from St. Paul.		Above lake Superior.	Above the ocean.
15	Summit four miles from Stillwater	327	929
15.5	Junction W. Wisconsin R. R. (cut 17 feet)	285	887
17.5	Broken descent to marsh (bottom)	151	753
17.5	Center of gravel ridge, one and a half miles from Stillwater (cut 50 feet)	171	773
19	Broken descent to high water at Stillwater	85	687
19	Low water in St. Croix lake at Stillwater	55	[illegible]67

Branch line of the St. Paul & Pacific R. R., from St. Anthony to Brainerd.

FROM THE RECORDS IN THE OFFICE OF THE CHIEF ENGINEER, C. A. F. MORRIS. ABSTRACTED BY N. H. WINCHELL.

Miles rom St. Paul.		Above lake Superior.	Above the ocean.
9.5	Junction at St. Anthony	240	842
17	Manomin (Fridley)	246	848
17	Rice creek (water level)	219	821
21.5	Coon creek (water level)	230	832
27	Anoka	281	883
27.5	Rum river (water level)	243	845
34	Itasca	289	891
39	Elk River station	294	896
43	Elk river (water level)	294	896
48	Big Lake station	338	940
56	Becker	375	977
63	Clear Lake station	395	997
73.5	St. Cloud, E. shore of Mississippi river	410	1012
75	St. Cloud, W. shore of Mississippi river	420	1022
	Mississippi river at St. Cloud bridge	363	965
	Mississippi river at Sauk Rapids (water)	386	988
76	Sauk Rapids station	402	1004
82	Watab station	451	1053
85	Little Rock river (track)	418	1020
85	Little Rock river (water)	405	1007
89	Rice's station	457	1059
95	Platte river (track)	467	1069
95	Platte river (water)	457	1059
96	Royalton	478	1080
106	Smooth surface to Little Falls (track)	512	1114
111	Smooth surface to Belle Prairie	528	1130
118.5	Summit	570	1172

Branch line of the St. Paul & Pacific R. R., from St. Anthony to Brainerd—continued.

Miles from St. Paul.		Above lake Superior.	Above the ocean.
120	Fort Ripley	556	1158
120	Nokasippi river (water)	537	1139
127	Crow Wing	584	1186
133.5	Buffalo creek	601	1203
133.5	Buffalo creek (low water)	570	1172
134.5	Summit between Buffalo and Buckhorn creeks	599	1201
136	Buckhorn creek (track)	562	1164
136	Buckhorn creek (low water)	587	1189
137	Broken surface to Brainerd (N. P. Junc.)	604	1206

Line of the St. Vincent branch of the St. Paul & Pacific R. R.

ABSTRACTED FROM THE RECORDS IN THE OFFICE OF THE CHIEF ENGINEER, C. A. F. MORRIS, BY N. H. WINCHELL.

Miles from St Paul.		Above lake Superior.	Above the ocean.
74	E. St. Cloud station	410	1012
74	Low water in Mississippi river at St. Cloud	363	965
75	W. St. Cloud	420	1022
78.5	Sauk river (track)	433	1035
78 5	Sauk river, first crossing (water)	416	1018
79	Sharp ridge (cut 15 feet)	437	1039
82	St. Joseph	471	1073
83.5	Watab creek (track)	459	1061
86	Sharp ridge (cut 17 feet)	486	1088
87.5	Broken surface to summit	536	1138
90	Broken surface to Avon	515	1117
94.5	Broken surface to Two rivers (water)	521	1123
6.5	Broken surface to Albany	586	1188
99	Broken surface to summit near 99's mile post	634	1236
101	Broken surface to Getchell's creek (water)	575	1177
103	Broken surface to Freeport (a summit)	624	1226
106	Broken surface to Sauk river, second crossing, (water)	557	1159
108	Broken surface to Melrose	596	1198
111	Smooth surface to third crossing of Sauk river, (track)	598	1200
111	Third crossing of Sauk river (water)	586	1188
114	Broken surface to summit (cut 15 feet), Sec. 24, T. 126, R. 34	656	1258

Line of the St. Vincent branch of the St. Paul & Pacific R. R.—continued.

Miles from St. Paul.		Above lake Superior.	Above the ocean.
116	Broken surface to fourth crossing Sauk river (track)	625	1227
116	Sauk river (low water)	600	1202
117	Smooth surface to Sauk Center station	640	1242
120	Broken surface to cut of fourteen feet	693	1295
121	Broken surface to summit (cut of seventeen feet	712	1314
122.5	Silver creek (track)	666	1268
125	Undulating surface to West Union station	722	1324
131	Broken surface to Osakis station	728	1330
133	Summit (Sec. 22, T. 128, R. 36)	793	1395
135	Broken surface to 135's mile post	727	1329
136	Nelson	754	1356
138	138's mile post	803	1405
139.5	Broken surface to creek (track)	759	1361
142	Broken surface to Alexandria	778	1380
149	Very broken surface to Garfield station	803	1405
158	Broken surface to Chippewa river (track)	760	1362
158	Chippewa river (water)	730	1332
160	Evansville station (cut twenty-eight feet, fill immediately of fifteen feet)	745	1347
161	Very broken surface to summit (cut of thirty feet)	769	1371
166	Very broken surface to lake Christina (cut and fill at Christina of forty-two feet)	623	1225
169.5	Very broken surface to summit (cut five feet)	687	1289
173.5	Very broken surface to St. Oloff	735	1337
176	Very broken surface to summit (cut three feet)	750	1352
179	Very broken descent to Pomme de Terre river (grade)	630	1232
179	Pomme de Terre R. (water)	596	1198
179	Pomme de Terre R. (bottom)	592	1194
180	Broken surface to Tumuli station	596	1198
186.5	Broken and irregular descent to Red river crossing (water)	462	1064
186.5	Red river (bottom)	417	1019
	NOTE.—*From mile post 131 to 188 there are frequent fills and cuts.*		
187	Red River Falls station	522	1124
192	Undulating, slow descent to 192's mile post	499	1101
200	Sec. 1, T. 133, R. 45	467	1069
204	Smooth surface to 204's mile post	464	1066
210	Sec. 15, T. 135, R. 45 (smoo h surface)	496	1098
212	Smooth surface to 212's mile post	505	1107
216	Smoth surface to 216's mile post	429	1031
220	Smooth surface to Sec. 31, T. 137, R. 45	419	1021
222	Smooth surface to Barnesville (track)	405	1007
222	Willow river (bottom)	390	992
238.5	Smooth surface, slow descent to Glyndon (N. P. R. R. Junction)	323	925
241.5	Smooth surface to Buffalo river (track)	321	923

Line of the St. Vincent branch of the St. Paul & Pacific R. R.—continued.

Miles from St. Paul		Above lake Superior.	Above the ocean.
241.5	Buffalo river (water)	308	910
241.5	Buffalo river (bottom)	303	905
246	Smooth, level surface to Averill station	317	919
253	Smooth surface to Felton station	315	917
259	Smooth surface to Borup station	311	913
266	Smooth surface to Wild Rice river (track)	309	911
266	Wild Rice river (water)	300	902
266	Wild Rice river (bottom)	295	897
268	Smooth surface to Marsh river (water)	290	892
268.5	Ada station	305	907
280	Smooth surface to Rolette station	293	895
285.5	Smooth surface to Beltrami station	303	905
286	Smooth surface to Sand Hill river	296	898
296	Smooth surface to Kittson station	286	888
302.5	Smooth surface to t p of first bluff, Red Lake R	262	864
302.5	Red Lake river (track on bridge)	266	868
302.5	Red Lake river (water level)	236	838
302.5	Red Lake river (bottom)	224	826
303	Top of bluff on N. side Red Lake river	269	871
	NOTE.—*The valley is just a mile across with single, well defined bluffs.*		
304	Smooth surface, gentle ascent to summit	288	890
310	Smooth surface to 310's mile post	304	906
320	Smooth surface to 320's mile post	286	888
330	Smooth surface to 330's mile post	243	845
333.5	Smooth surface to Snake river (water)	241	843
340	Smooth surface to 340's mile post	251	853
343.5	Smooth surface to Middle river (track)	245	847
343.5	Middle river (water)	234	836
343.5	Middle river (bottom)	231	833
350	Smooth surface to Sec. 8, T. 157, R. 48	239	841
351	Smooth surface to Tamarack R. (track	231	833
351	Tamarack R. (water)	217	819
351	Tamarack R. (bottom)	215	817
375	Smooth surface to S. branch of Two rivers (track)	216	818
375	S. branch of Two rivers (water)	203	805
375	S. branch of Two rivers (bottom)	194	796
380	Smooth surface to North branch of Two rivers (track)	201	803
380	N. branch of Two rivers (water)	187	789
380	N. branch of Two rivers (bottom)	181	783
392	Smooth surface to 392's mile post	196	798
394	Slow, irregular descent to the immediate bank of Red river (track)	189	791
394	St. Vincent (bank of Red river)	190.5	792.5
394	St. Vincent (bottom of Red river)	142	744
394	St. Vincent (high water of 1866)	185	787
394	St. Vincent (usual water surface)	156	758

On the line of the Southern Minnesota R. R.

FURNISHED BY CHIEF ENGINEER H. W. HOLLEY.

Miles from La Crosse.		Above the Miss. R. at La Crosse.	Above lake Superior.	Above the ocean.
	Grand Crossing Miss. R. opposite La Crosse......	12	36	638
30	Rushford..............................	96	120	722
48	Lanesboro..............................	215	239	841
53	Isinour's (Sec. 20, T. 103, R. 10)................	273	297	899
59	Fountain..............................	676	700	1302
83	Grand Meadow (Sec. 24, T. 103, R. 15)...........	712	736	1338
	Sec. 13, T. 103, R. 16..........................	788	812	1414
103	Ramsey (grade Mil. and St. Paul R. R.)..........	588	612	1214
118	Hayward..............................	622	646	1248
166	Winnebago City..............................	470	494	1096
167	Water in Blue Earth river one mile west of Winnebago City..............................	388	412	1014
	Sec. 25, T. 104, R. 30..............................	490	514	1116
	Sec. 1, T. 103, R. 33..............................	599	623	1225
	Sec. 25, T. 104, R. 36..............................	765	789	1391
212	Water in Des Moines river..............................	662	686	1288
	Heron lake (water)..............................	777	801	1403
	Graham lake (water)..............................	819	843	1445
	Sec. 3, T. 102, R. 22..............................	701	725	1327
	Sec. 33, T. 101, R. 21..............................	636	660	1262
	Sec. 36, T. 101, R. 24..............................	608	632	1234
	Sec. 31, T. 101, R. 24..............................	631	655	1257

IV.

THE SURFACE GEOLOGY.

The amount of time devoted to the phenomena of the drift has necessarily been small. A sufficient number of facts on which to base scientific opinions have not yet been obtained to warrant the announcement of any discoveries; observations have been made however, that confirm theories lately advanced as to the origin of the clays which make up a great portion of the drift of the Northwest. The great mass of clay charged with gravel, and often with boulders, is found to be of glacier origin. This deposit is generally blue, but in the eastern part of the state it is reddish or copper colored. It is made up almost entirely of transported materials, and its red color in the direction of the iron ore beds of the lake Superior region, seems to be due, as some time ago suggested by Col. Charles Whittlesey,* to the greater contained quantity of iron oxide, consequent on the continued action on and the transportation of large portions of those rocks by the forces of the glacial period. This deposit lies on the striated rocky surfaces, or is separated from them by a thin stratum of gravel or sand which usually supplies water. The boulders embraced in this hardpan deposi are very often striated and polished in the same manner as the bedded rocks below. It also embraces, but rarely, lenticular beds of stratified gravel, or sand and gravel mixed without stratification. In some instances it has been seen to inclose nests of boulders and gravel, compactly deposited and detached from other similar deposits. In other cases a spur or lip from the hardpan will rise above the main mass, and, bearing off diagonally to the right or left, will partially enclose on the lower side a few feet of stratified materials of sand and gravel. Indeed along the valley of the Mississippi, and in regions of rough, rocky surfaces its upper portion is very apt to be replaced by stratified deposits of sand and gravel variously

*_On the fresh water glacial drift of the northwestern states._ By Charles Whittlesey. _Smithsonian contributions to knowledge_, 197.

alternating with each other and with irregular patches of the same.

In these cases the boulders, derived from the original unassorted mass, are apt to lie also in layers or pockets by themselves, their interstices filled with coarse gravel. Throughout much of the central portion of the state, and especially in Carver and McLeod counties, where it has recently been exposed in numerous cuts along the line of the Hastings and Dacotah railroad, this hardpan, or unassorted glacier drift, rises to the surface with no overlying stratified beds. Large boulders of more northern origin are uniformly met in these cuts, even if they be but a few feet below the surface. Sometimes a thickness of more than a hundred feet may be seen presenting no essential variation in outward characters or contents. Its color when freshly exposed at considerable depth is blue, but it has everywhere become oxidized below the surface to the depth of fifteen or twenty feet, and it then assumes a yellowish ash-color. It has been noticed that in Minnesota this deposit varies greatly in thickness. There is an area in the southeastern part of the state where very little of it is found. The rocks stand out prominently in bluffs and terraces caused by their various capacity to withstand the elements, covered with very little besides the decomposed debris of their own beds. Yet in this portion of the state, which seems to be an extension of the so-called "driftless region" of Iowa, the valleys on being excavated for cellars and wells reveal a clay charged with pebbles and sometimes large boulders. This clay is said to contain fragments of wood and leaves half decomposed. Sufficient examination has not yet been made to show the relation of this blue clay in the southeastern portion of the state, containing vegetable deposits, with the vast sheet of blue clay containing, so far as known, no vegetable or other remains, which is spread over a greater portion of the entire state. It seems, however, to be of older date, and may consist of the remains of a previous glacial sheet, which, under the action of the last glacial epoch was subjected to erosion and wash but was not replaced by fresh deposits. In that way the vegetable growths of the surface, accumulating between the periods of the two glacial epochs, would be buried in the depressions to various depths beneath the debris from the hillsides, and considerable beds of peat or even an entire soil would be preserved, while toward the north the movement of the glacier ice entirely destroyed and removed the ancient soils. The thickness of this hardpan at Fargo, D. T., on the line of the Northern Pacific railroad, as revealed by the drilling of a well, was found to be one hundred and fifteen feet. It there lies below a hundred and five feet of variously stratified clay, gravel and sand.

This deposit is spread out in a vast sheet over much of the states of Minnesota, Wisconsin, Iowa, Illinois, Michigan, Indiana and Ohio, and it is locally covered by a fine, stratified clay which has been named by the geologists of Canada "Erie clay," although the two have sometimes been confounded. It has never been known to contain fossils, either of vegetables or animals. As clay it is entirely unstratified, but it may embrace irregular beds of stratified materials, and above may become replaced by assorted gravel and sand, the whole being of the same age. As to its manner of deposition it is believed to be the immediate product of the ice of the glacier, and was gently let down on the surface of the rocks that it so effectually conceals, by the slow thawing and withdrawal of the ice. It must have been largely frozen in the body of the ice in regions far to the north, but by the superficial wasting of the glacier as it advanced into warmer latitudes, it gradually formed a layer covering the surface of the ice in much the same way as it now covers the rock. Such underground ice is known to exist at the present time in several places in northern latitudes. Wherever streams of water gathered, incident to the dissolution of the glacial ice, the materials of the drift were assorted and often handsomely arranged in oblique stratification. This would occur especially along the main valleys, and in crevasses that might result from the passage of the ice over rough, rocky surfaces. Streams running in such crevasses would wear their beds deeper into the ice-sheet and perhaps to the bed-rock itself. All drift materials precipitated into such crevasses by the motions of the ice would be washed and assorted, and the finest portions would be entirely carried away. Upon the entire withdrawal, or dissolution of the ice-sheet a ridge of gravel and sand, containing boulders and suggesting the common name of "hog's back," would mark the place where such a stream, had its bed. When the slope of the country was away from the foot of the glacier, or in the direction of its motion, the streams would be likely to carry away the clayey portions of the drift, leaving only stratified gravel and sand along the valleys of the water courses; but where the slope of the country was toward the ice foot, as in the Maumee valley, in Ohio, and in the valley of the Red river of the North, the fine parts would be laid down over the unstratified drift in horizontal laminations of fine clay and sand. A lake of standing water would be formed about the foot of the ice, with an outlet southward through the lowest drainage valley accessible.* It is authentically reported that at the present time this very circumstance occurs in the Red river valley in seasons of unusual severity. The mouth of the river is completely frozen, or so obstructed by ice, that the whole country for several miles in width is submerged sometimes below forty feet of water. In such cases the discharge must be by the Minnesota valley, Big Stone lake and lake Traverse becoming one. About ten years ago, when these lakes were so united, an effort was made, and nearly with success, to float a steamboat across the continental water-shed from the Minnesota valley into that of the Red river of the North. There are many indications that the Red river region was for a long time covered by a lake of fresh water and had an outlet by way of the Minnesota valley into the Mississippi river.

Overlying this hardpan in much of the southern part of the state, and covering especially those portions of the state where the hardpan exists in small quantities, is a sandy loam which forms a very productive surface soil, and is especially exhibited on the bluffs along the Mississippi river, where it has been named, in states further south, "The Bluff Formation." The distribution of this material over the state is not well known, and its origin remains yet in doubt. Where it reaches its greatest development it is perfectly unstratified. Its characteristics are very uniform, and its aspect and composition are perfectly homogeneous. It has been attributed to the prevalence of a fresh water lake over much of the Northwest. It may perhaps as reasonably be ascribed to the insoluble residue from the rocks *in situ*, and its distribution to the effect of surface drainage. The pulverizing action of the prairie fires on the rocks, or on pebbles contained in the drift may account for the existence of this loam in places where it covers the glacier drift

*Compare "On certain physical features of the Upper Mississippi river." By Gen. G. K. Warren, *American Naturalist* for Nov., 1868.

at points remote from streams. It contains, in the valleys, the shells of the fresh-water molluscs, and seems there to be perfectly comparable to ordinary alluvium. The immediate surface of this loam, and of the soil generally, in the central and southern portions of the state, is blackened by the charcoal of innumerable fires that have passed over the surface, and by decomposing vegetable remains.

The drift about St. Anthony and St. Paul shows the following general section:

No. 1.—Bluff	6 to 10 feet.
No. 2.—Assorted materials, often nicely stratified, sometimes replaced by a mass of glacier-marked (!) boulders and cobble stones mingled with gravel. This seems to be due to the removal by water of the clayey portions of the hardpan. It not unfrequently shows very large blocks and masses ot the Trenton flags ("Lower shell limestone," of B. F. Shumard)	10 to 20 feet.
No. 3.—Hardpan, seen	25 feet.

V.

SKETCH OF THE GEOLOGY OF MINNESOTA.

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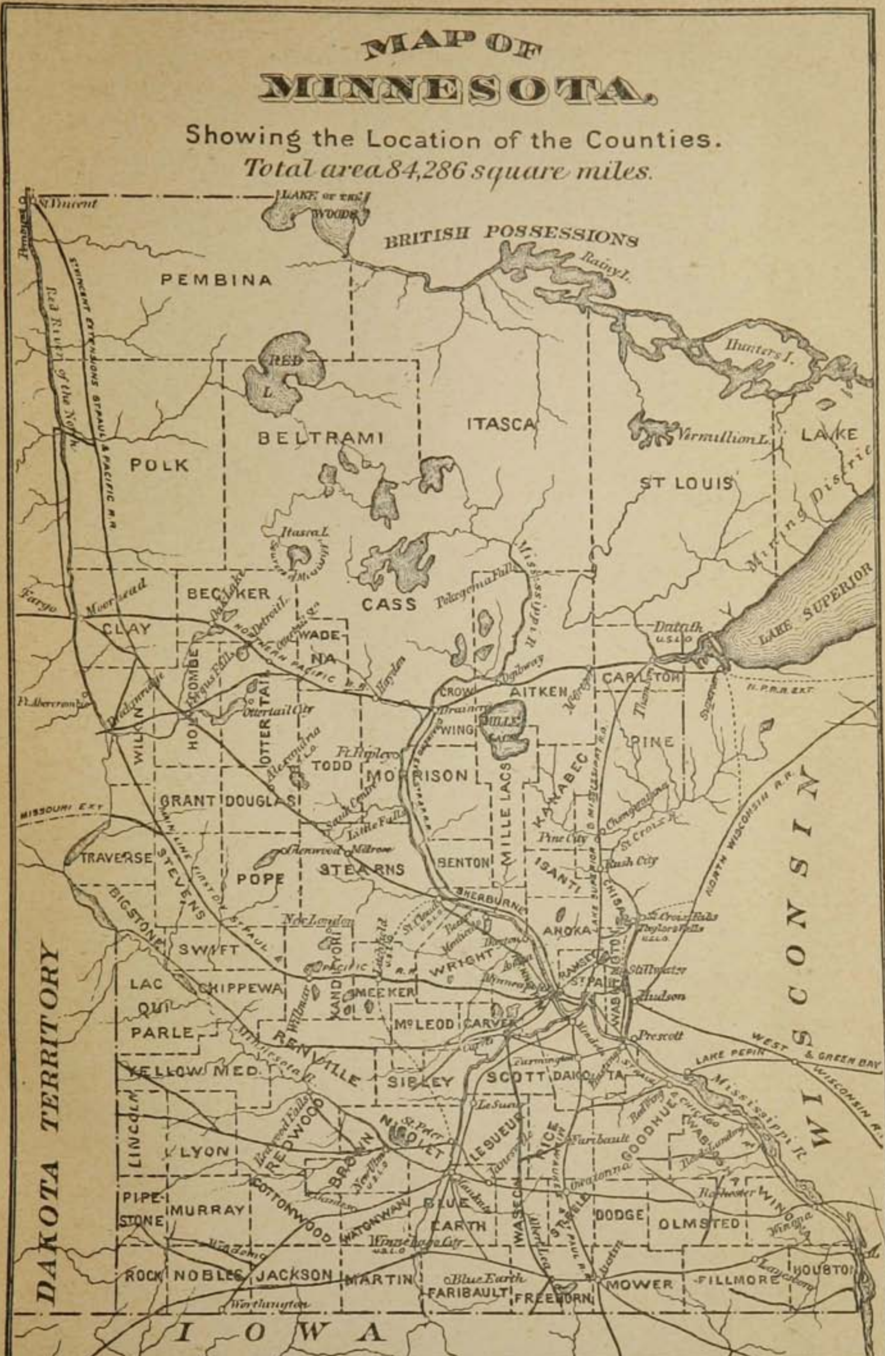
1. GRANITIC AND METAMORPHIC ROCKS.

(a.) *Their area.*

Under this designation are embraced all rocks that lie below the Potsdam sandstone. It covers not only the granitic nucleus which first appeared as dry land, and those trappean rocks that are with little difference of opinion pronounced the result of purely igneous forces, but also the vast thickness of truly metamorphic strata included under the terms *Laurentian* and *Huronian.*

These rocks occupy a great portion of the state of Minnesota, crossing it in a rudely wedged-shaped belt from the northeast to southwest. The southern margin of this belt enters the state from Wisconsin about three miles below the mouth of Kettle river, crosses the Mississippi about three miles below the mouth of Clear Water river in a southwesterly direction. It also crosses the Minnesota river about three miles below Fort Ridgely and probably


MAP OF
MINNESOTA.
Showing the Location of the Counties.
Total area 84,286 square miles.
BRITISH POSSESSIONS
LAKE OF THE WOODS
Rainy L.
Hunters I.
PEMBINA
BELTRAMI
ITASCA
POLK
Vermillion L.
LAKE
ST LOUIS
LAKE SUPERIOR
Duluth
Itasca L.
CASS
BECKER
CLAY
Moorhead
Fargo
WADENA
CROW WING
AITKEN
CARLTON
PINE
MILLE LACS
KANABEC
MORRISON
TODD
OTTER TAIL
WILKIN
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
SHERBURNE
ISANTI
ANOKA
BIGSTONE
SWIFT
LAC QUI PARLE
CHIPPEWA
MEEKER
WRIGHT
RAMSEY
WASHINGTON
St Paul
Hudson
Prescott
Stillwater
McLEOD
CARVER
RENVILLE
YELLOW MED.
SIBLEY
SCOTT
DAKOTA
LINCOLN
LYON
REDWOOD
BROWN
NICOLLET
LESUEUR
RICE
GOODHUE
WABASHA
PIPE STONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
Blue Earth
Faribault
Owatonna
Rochester
Winona
DAKOTA TERRITORY
IOWA
WISCONSIN
Mississippi R.

leaves the state near the northern line of Pipestone county. The northern or northwestern boundary of these rocks enters the state from the north about midway between the lake of the Woods and the Red river of the North, in a southerly and then a southeasterly direction, to the vicinity of Pokegama falls, where it changes its course and runs in a southwesterly direction, passing approximately through Cass, Todd, Stevens and Traverse counties to the western boundary of the state. These rocks thus form a great anti clinal axis, or backbone from which the later sedimentary rocks dip in opposite directions to the southeast, and to the west and northwest, their area being something more than one third of the entire state. North of lake Superior they produce a rough, and even mountainous tract of country which is marked by a series of ridges or ranges of upheaval NE. and SW.; but toward the southwest their original uneven surface is so evenly and deeply covered with drift that they are but rarely seen, except in the valleys of the streams, the country assuming the character of a rolling and more or less wooded, or of a level and open prairie.

(b.) *Their general lithological characters.*

These rocks have been included under the general term of *Azoic*, from the absence of organic remains. The geologists of Canada have, however, described within a few years a strangely concretionary or laminated alternation of pyroxene and carbonate of lime, taken from the *Laurentian system,* which on microscopical examination has disclosed an organic structure resembling that of the *foraminifera*, and has been named *Eozoon Canadense* by Dr. J. W. Dawson.* This discovery carries downward the horizon of the beginning of animal life several thousand feet below the base of the *Potsdam sandstone;* and the appropriate term *Eozoic* has been used to describe the earliest of fossiliferous rocks, comprising the *Laurentian* and *Huronian* systems. With this exception no fossil remains have been found below the *Potsdam sandstone.*

The lithological and mineralogical characters of this belt of granitic and metamorphic rocks are very complex and variable. The original upheaved nucleus was granitic, or syenitic and granitic, and this character prevails in the oldest and highest knobs and hills, around which the highly metamorphosed slates and gneisses

*In this fossil the pyroxene is sometimes replaced by serpentine, or loganite, (or by pyralolite?) and the calcite by dolomite.

are arranged in upturned and even vertical beds. Intercalated with these disturbed beds are numerous injected beds and dykes of volcanic trap, the igneous origin of which cannot be doubted. The metamorphism consists in a decomposition and recrystallization, through the combined action of heat and chemical affinity, of the first sedimentary strata, producing from sandstones, limestones and shales, talcose argillaceous slates, gneiss, quartz and saccharoidal marble, and in some instances immense masses of specular and magnetic oxide of iron. The close of this disturbance involved the overlying *Potsdam sandstone*, or at least the "red sandstones" of the Northwest, but in Minnesota it antedates, so far as known, the sandstones of the St. Croix valley and the *Lower Magnesian limestone.* It seems to have continued to the close of the deposition of the "red sandstone," and to have terminated prior to the deposition of the Lingula beds, which lie without disturbance, as far as known, on the ejected traps, and between the red sandstone and the light-colored quartzose sandstone which characterizes the upper Mississippi valley. This disturbance was the cause of fissures and dislocations in the rocky crust, which by slow degrees became filled with the various materials composing the metalliferous veins.

In 1849 Col. Charles Whittlesey classified these rocks in northern Wisconsin, in the following desecending order: (*Owen's geol. sur. of Wis., Iowa and Minn., p. 425.*)

1. SEDIMENTARY.
   a. Red sandstone (*not belonging to the metamorphic series.*)
   b. Black slate.
   c. Conglomerate.
2. TRAPPOUS ROCKS, OR THOSE OF VOLCANIC ORIGIN.
   a. Black and red amygdaloid, and greenstone trap.
   b. Augitic, hornblendic and feldspathic rocks, embracing syenites and granites of the same age.
3. METAMORPHOSED ROCKS.
   a. Hornblendic slates.
   b. Iron slates.
   c. Black slates, in large, thin, rectangular sheets.
   d. Talcose slates.
   e. Slaty quartz.
4. GRANITIC.
   a. Syenite.
   b. Granite occupying the country south of the mountain range or uplift, and are the oldest rocks seen.

Messrs. Foster and Whitney, in a report on the lake Superior land district in 1851, give them the following arrangement in descending order:

AZOIC SYSTEM.
- Beds of quartz and saccharoidal marble.
- Chlorite, talcose and argillaceous slate.
- Gneiss, mica and hornblende slate.

IGNEOUS ROCKS, OF VARIOUS AGES.
- *Trappean or volcanic rocks.*
  - Masses of specular and magnetic oxide of iron.
  - Hornblende and serpentine rocks.
  - Basalt, amygdaloid.
  - Greenstone, or doleryte, porphyry.
- *Plutonic rocks.*
  - Feldspar and quartz rock.
  - Syenite.
  - Granite.

The *Potsdam sandstone*, or that portion which is equivalent to the red sandstone, overlies all the forgoing, and although very much broken by intrusions and overflows of trap, and often reduced to the form of a conglomerate, or a volcanic tufa, is not regarded by Foster and Whitney as belonging to the series of metamorphic rocks.

(c.) *Their economical value.*

In the state of Minnesota these rocks are known to contain variable quantities of gold, silver, copper and iron. As yet no extensive exploitation of these metals has been made. Veins of gold and silver bearing quartz are known to occur in the vicinity of Vermilion lake, and at other places on the north shore of lake Superior. Recently gold has also been reported from the vicinity of Red lake. Veins carrying native copper, as well as the sulphuret and carbonate, also occur on the Kettle river, and at Taylor's Falls on the St. Croix river. Iron ore in unlimited quantities is said to exist in the dividing ridge between lake Superior and Vermilion lake. Other materials of economic importance also pertain to these rocks. The gray "granite" quarried at St. Cloud contains both mica and hornblende (or pyroxene); the quartz is slightly amethystine, or smoky, and makes up about one half the bulk of the whole, while unmistakable feldspar is almost entirely wanting. It has also a very few minute crystals of pyrites. It is being considerably introduced into some of the largest structures both in St. Paul and Minneapolis, and in various cities of the Mississippi valley. Its composition renders it a very durable building material, even more enduring than typical syenite or granite. Roofing slate is also one of the economical products of the metamorphic rocks, known to exist in Minnesota. There is no doubt but unlimited quantities of this material will yet be found within the state. The efforts that have hitherto been made to manufacture this article and introduce it into the markets of the Northwest, in the vicinity of Thomson, have not been very successful. It is believed, however, that the fault lies not in the material itself, but in the manner it has been handled. For fire-stone the talcose slates, associated with the Huronian series in the eastern extension of these rocks in Michigan and Canada, are very well adapted. These rocks also ought to supply steatite, or soapstone, and no doubt hold considerable beds of variegated and saccharoidal marble. It will be a prominent object, in the progress of the survey, to bring these various economical resources into careful observation and investigation. At the present time little is known beyond the foregoing statement of facts, although private parties have made more or less detailed surface exploration.

2. THE POTSDAM SANDSTONE.

(a.) *Preliminary considerations.*

This term is strictly applicable only to the sandstones of New York state, to which the name was first given, and to the equivalents of those strata in their extension through the west. It has been abundantly proved that the red sandstones of lake Superior, however disturbed and changed locally, or however much increased in thickness by the agency of volcanic outbursts, are the exact equivalents of the New York *Potsdam.* They occupy the first position over the metamorphic slates of the *Huronian* rocks on which they lie unconformably, and from which they differ in being but slightly and only locally metamorphosed. They retain usually their evidently sedimentary characters, and have not well preserved fossil remains. By the Canadian geologists the term *Potsdam* is made to cover a group of arenaceous strata, the lower portion only of which is the real equivalent of the New York Potsdam.*. In Michigan the name is given only to the red sandstones, the overlying light colored sandstones being regarded as a part of the *Calciferous sandrock.*** Dr. Houghton as early as 1841 distinctly stated in his annual report to the Michigan Legislature, that the "upper gray sandstone" is not conformable with the "lower or red sand-

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* See *Geology of Canada*, 1863. p. 87.

** See *Biennial report of progress*, 1860, p. 49.

stone and shales." (See his report for 1841, p. 19.) In Wisconsin the same sandstone occupies a wide circular belt surrounding a granite center. The overlying light-colored sandstones are found there to lie unconformably on the red sandstones where they have been tilted by volcanic agency.† Dr. C. A. White, of the geological survey of Iowa, has described a red sandstone or quartzyte, occurring in outcrop on the Big Sioux river and in southwestern Minnesota, and given it the special name of *Sioux quartzyte*, proving conclusively that it is both older, and unconformable with the light-colored sandstones that occupy a conspicuous place in the bluffs of the upper Mississippi, below the *Lower Magnesian limestone.*†† At New Ulm, and and at other points in southwestern Minnesota, the same quartzyte forms some of its characteristic outcrops. It rises suddenly above the superincumbent drift, exposing at New Ulm about 350 feet, with a dip of thirty-six degrees to the north. Its features here are easily identifiable with those of the *Potsdam* at the rapids in the St. Mary's river, at Sault Ste. Marie, Mich. In their passage to the west the overlying light-colored sandstones seem to become more largely developed. They acquire a thickness, including the intercalated beds of shale, of about six hundred feet, in their exposures along the Mississippi river.

On the other hand Dr. D. D. Owen, finding these upper sandstones abutting undisturbed against the trap outbursts at the falls of the St. Croix, supposed at once that he reached there the true paleozoic base.‡ Fossils gathered there, and at other points on the upper Mississppi, in these and associated beds, were described as coming from the *Potsdam sandstone,* and were supposed to belong to a horizon much lower than that of the *Lingula beds* of the *Potsdam* of New York. The name has been still further removed from its original use by the Iowa geologists, *in its application only to these upper beds*, and in giving the name *Sioux quartzyte* to the western representative of the original *Potsdam*. Dr. Owen, although he recognized many points of difference between the lake Superior and New York *Potsdam*, and these light-colored sandstones of the St. Croix and upper Mississippi, seems not to have noted the important fact that the former are everywhere subject to distortions and fractures by volcanic forces, while the latter are

† R. D. Irving, on the Age of the Quartzytes, &c., of Sauk county, Wis., *Am Jour.*, Feb., 1872.

†† *Geology of Iowa*, 1870. Vol. I., p. 167.

‡ *Geological report on Wisconsin, Iowa and Minnesota*, p. 50.

never known to be disturbed by such causes. It is true that he embraces both the red and the light-colored sandstones in the designation of "Potsdam," and argues at length to prove the greater age of the red.*

It is in accord with geological precedent, therefore, to separate these two sandstone formations under different names, retaining the name of *Potsdam* for the older, and giving provisionally the name of the St. Croix river, on which they are best exposed, to the latter:

The following reasons may be assigned:

1st. The *Potsdam* beds were laid down before the close of the volcanic disturbance so evident in the rocks of the early Silurian and pre-Silurian ages; the *St. Croix* beds were deposited and still lie in horizontal layers, unconformably not only over the *Laurentian* and latest trappean rocks of the Northwest, but also on the upturned beds of the *Potsdam.*

2nd. The observations of the New York and Canadian geologists place the earliest *Lingula* beds near the top of the *Potsdam sandstone;* this separation of the *St. Croix* beds does not invalidate their conclusions, but fixes the *observed* paleozoic base in the Northwest at some point higher than that of the *Potsdam.* The wonderful abundance of fossil Lingulas and other forms in the shale abutting against the trap at the falls of the St. Croix would furnish presumptive evidence of their existence prior to that outburst. They simply have not been seen.

3d. The lithological characters of the *Potsdam* beds are uniformly different from those of the *St. Croix* beds. The former are hard and often vitreous, usually of a brick-red color. Their bedding is very distinct, and often separated into slaty layers by partings of red shale. They are strongly marked by the so called fucoidal impressions. They are frequently ripple-marked and sun-cracked. The latter are white or buff-colored, often friable, and constitute a heavy bedded or massive sandstone, of handsomely rounded quartzose grains.

4th. They differ in chemical composition. The *Potsdam* beds contain "a considerable percentage of alumina, ranging sometimes as high as twenty per cent., while of silica there is often less than fifty per cent. Their peculiar red color is due to the presence of a large proportion of peroxide of iron, with a much smaller proportion of protoxide" (Owen).

**Geological survey of Wisconsin, Iowa and Minnesota, p.* 187.

The *St. Croix* beds "commonly contain ninety-two per cent. and upward, of silica, while of alumina and oxide of iron taken together they have seldom more than three per cent" (Owen).

5th. They are separated by a fifty-foot bed of *Lingula shale* which lies at the bottom of the *St. Croix* beds.

6th. The *Potsdam sandstone* has a thickness of at least four hundred feet;* the *St. Croix sandstone* also has a thickness of over five hundred feet. It is more in keeping with the canons of geological nomenclature to give separate titles to formations so well defined and so largely developed.

7th. The evidence of paleontological difference is perhaps the strongest reason for separating these sandstones. The fossils of the *Potsdam sandstone* in New York are *Lingula antiqua* (Con.) and *Lingula prima* (Con.), a *Discina* (or *Orbicula*), and uncertain impressions supposed to be of a *Pleurotomaria* and of crinoidal remains. A species of *Theca* has also been described from Keeseville. According to Prof. James Hall but three species are known from the Potsdam of New York. (Foster & Whitney's *report on lake Superior*, Part II. p. 230). The fossils of the *St. Croix sandstone* are, according to Dr. Owen, (*Rep. on the geological survey of Wisconsin, Iowa and Minnesota*, p. 624) the following:

Dikelocephalus Minnesotensis, (On.)	For. 1. d.	5th trilobite bed,	90 to 100 feet below	F. 2.
" *Pepinensis*, (On.)	" "	" "	"	"
" *Miniscaensis*, (On.)	" "	3rd "	200 to 220 feet	"
" *Iowensis*, (On.)	For. 1. b.	1st trilobite bed	more than 500 feet	"
" *granulosus*, (On.)	For. 1, d.	3rd "	" 200 feet	"
Lonchocephalus Cippewaensis, (On.)	"	3rd or 4th "	" ?	"
" *hamulus*, (On.)	For. 1. d.	3rd "	200 to 220 feet	"
Crepicephalus Minnesotrnsis (On.)	" "	"	"	"
" *Wisconsensis* (On.)	" "	"	"	"
Monocephalus Minnesotensis, (On.)	" "	"	"	"
Euomphalus (*species undet.*)	For. 1 f.	6th "	50 feet	"
Lingula pinnaformis, (On.)	" b.	*Lingula shales*,	600 feet	"
Lingula prima, (Con.) ?	" ?	"	"	"
Lingula ampla, (On.)	" c.	"	"	"
Lingula antiqua, (Con.)	" ?	"	"	"
Orbicula prima, (On.)	" c.	"	"	"
Obolus Apollinis,	" d.	?	?	?
Orthis (species ?),	" d.	?	?	?
Crinoidal remains,	" d.	?	?	?

To these Mr. Hall adds from Wisconsin.†

Lingula polita, (H.)	*Conocephalites*, (two species.)
" *Aurora*. (H.)	*Arionellus*.
Theca primordialis, (H.)	*Agnostus*.
Serpulites Murchisoni.	*Platyceras*.
Graptolithus Hallianus, (Prout.)	*Orthis Barabuensis*, (H.)
	Orthis, (species?)

*Dr. Owen makes the thickness of the Potsdam (red sandstones of lake Superior) over five thousand feet. See Owen's *Report on Wis., Iowa and Minnesota*, p. 193.

†*Geology of Wisconsin* vol. I., p. 20.

The "Menominee trilobite bed," of Foster and Whitney is placed by Owen in the *St. Croix sandstone.* Of all the above species the real *Potsdam sandstone* has afforded in New York but three species and those of genera that range not only through the Lower Silurian, but have maintained an existence to the present time.

8th. Messrs. Foster and Whitney, recognizing the paleontological difference between the *Potsdam sandstone* of New York and the *St. Croix sandstone* of the Northwest, yet laboring to prove their horizontality, suggest that the striking fossils of the latter may yet be found in the *Potsdam* of New York,† having been hitherto overlooked. It would seem more likely that the few fossils of the eastern *Potsdam* have escaped the eye of western geologists in examining rocks of that horizon, than that the singular forms of animals found in the *St. Croix sandstone* of the west have escaped the eye of eastern geologists. The following table of the number of species found in the state of New York, and the lake Superior district is of interest in this connection. It was prepared by Prof. James Hall, and is published in Foster and Whitney's *Report on the lake Superior land district.* Part II, p. 230.

	Lake Superior district.	New York.	
Potsdam sandstone	3	3	
Calciferous sandstone	4	13	
Chazy limestone	10	45	
Birds Eye, Black River and Trenton	64	220	And thirty species common to the Trenton and other groups.
Hudson River group	31	54	Besides thirty other species common to this and the preceding groups.
Clinton group / Niagara group	26	298	
Upper Helderberg	16	?	

Inspecting this table we see the number of fossils found in the *Potsdam* in the west, including also those enumerated by Mr. Hall from the *St. Croix sandstone*, is equal to those from the *Potsdam sandstone* of New York. From the *Calciferous* the proportion of fossils found in New York is 225 per cent. in favor of eastern geologists. From the *Chazy limestone* the proportion is 350 per cent. in favor of eastern geologists. From the *Birds Eye*, *Black River* and *Trenton* limestones the proportion is 244 per cent. in favor of eastern geologists. From the *Hudson River group* the proportion

† Foster and Whitney's *Report on the lake Superior land district.* Part II, p. 134.

is 74 per cent. in favor of eastern geologists. From the *Clinton* and *Niagara groups* the proportion is 1050 per cent. in favor of eastern geologists. From the *Upper Helderberg* the proportion is not known, but probably would exceed the per cent. of any of the other formations, in favor of the eastern geologists. This only shows the greater scrutiny with which the formations have been observed in New York than in the lake Superior district, and inferentially that the fossils of the *St. Croix sandstone* have not been overlooked in New York. It seems more reasonable to suppose the *St. Croix sandstone* is only another illustration of the intercalation of arenaceous sediment in the Lower Silurian of the Northwest, creating really a new member of that series of rocks and introducing its own fossils, and that the paleozoic base of the *Potsdam* in New York has not yet been observed in the Northwest.

Notwithstanding these considerations it has not been thought best to attempt the delineation of the areas of these sandstones separately on the preliminary geological map accompanying this report. They are there colored as one formation, under the double designation of *The St. Croix and Potsdam sandstones.*

According to Dr. Owen the following table shows the most persistent elements of stratification of these great sandstone formations. [See *Geol. rep. on Wis., Iowa and Minn.*, p. 52].

f.	Sixth trilobite bed.	Quartzose, light-colored sandstones of various degrees of induration, with intercalations of beds of magnesian limestone, with glistening, crystalline facets and calcareo-siliceous oolite produced by rounded grains of quartz encased in calcareous cement. containing *Euomphalus* and imperfect trilobites. Locally with a band of green earth	ft. 50 to 85
		Mammillary and botryoidal layer of white sandstone; sometimes banded with yellow..	5 to 6 inches.
e		Thick beds of soft, yellowish and brown sandstone, sometimes with botryoidal, hard, projectig concretions; passing downward into fine-grained, soft sandstones approaching tripoli....................................	ft. 40 to 50

			FT.
	Fifth trilobite bed.	Ash-colored and yellowish argillo-calcareous and magnesio-calcareous beds, containing *Dickelocephalus Minnesotensis*, Stillwater trilobite bed....	8 to 10
		Green, red and yellowish sandstones with thin, schistose, dolomitic intercalations	40
		Upper, brown dolomitic layers, containing *Orthis*, *Lingula*, and columns of *Crinoidea*, as at La Grange mountain........	4
d.	Fourth trilobite bed.	Alternations of yellow, laminated sandstones with green particles disseminated........	5
		Marine Mill trilobite grit........	5
		Fucoidal layers, and thin-bedded green and yellow sandstones: at their base often a band of about six inches of green earth used by the Indians as a pigment........	30 to 40
		Green and red sandstones charged with silicate of iron........	5
		Loose green sand, and soft green sandstone........	15
	Third trilobite bed.	Micaceous sandstone containing *Dikelocephalus Miniscaensis*, *D. granulosus*, &c........	3
		Alternations of green and ferruginous sandstones........	20
		Micaceous sandstones containing *Dikelocephalus Miniscaensis*, &c........	2
		Thin layers of green sand alternating with green earth, impregnated with silicate of iron........	30 to 40
		Lower, brown siliceo-calcareous and dolomitic bands of Mountain island and elsewhere........	4
		Soft, thin-bedded sandstones with scales of mica disseminated........	10 to 15
c		Coarse Lingula grit, green, yellow, sometimes almost white........	100 to 130
	Second trilobite bed.	Fine grit, place of the Menominee trilobite grit(?), white and yellow sandstones and *Obolus* layers of Black river........	15
b.	First trilobite bed.	Ferruginous trilobite grits, schistose sandstone containing fork-tailed trilobite beds and *Obolus* layers........	1 to 8
		Magnesio-calcareous rock with *Obolus* and fork-tailed trilobites	3
		Highly fossiliferous, schistose, siliceo-calcareous layers interlaminated with argillaceous, marly beds, charged with sulphate of iron; the former full of *Lingulæ* and *Orbiculæ*. Falls of the St. Croix........	50
a.		Sandstones with oblique lines of deposition, alternating with pebbly sandstones and coarse grits of the Chippewa, Black and Wisconsin rivers, near the falls........	50 to 100
		Place of the lake Superior ferruginous and argillaceous sandstones, shales and conglomerates........	5000

(b.) *Area of the St. Croix and Potsdam sandstones.*

The area here described embraces that of the light-colored quartzose beds of the St. Croix and upper Mississippi valleys, and of the ferruginous and often metamorphosed red sandstones which lie below them. It can only be defined approximately. It is separated by the area of the granitic and metamorphic rocks into two belts, one lying along the southeast side of that area and the other along the northwest side. The former has a width on the St. Croix river extending from about four miles below the mouth of Kettle river to a point about six miles below Franconia. It runs diagonally across the state toward the southwest, including the counties of Chisago, the southern part of Pine, Isanti, the northern half of Anoka, the most of Sherburne, Wright, the western half of Carver, the eastern half of McLeod, the central portion of Sibley, the most of Nicollet, the northwest corner of Blue Earth, the greater portions of Brown and Watonwan, Cottonwood, Murray, Pipestone and Rock, with the northern portions of Jackson and Nobles. The northwestern area of these sandstones is supposed to include the counties of Traverse, Grant, Otter Tail, the northern halves of Douglas and Todd, Wadena, the most of Cass, and the central portions of Beltrami and Pembina. There are likewise isolated outliers of these sandstones even within the area of the granitic and metamorphic rocks, and a small area also in the eastern part of the state, in Carlton and St. Louis counties, near the western extremity of lake Superior.

(c.) *Lithological characters of the St. Croix and Potsdam sandstones.*

The general lithological characters, and the differences between the *St. Croix* and the *Potsdam* sandstones have been sufficiently set forth under the head of *Preliminary considerations.* It only remains to add special sections observed.

The lowest rock observed within the state, lying above the slates of the metamorphic series, is believed to be the red quartzyte seen at Redstone, near New Ulm. Such stone is said also to occur on the upper tributaries of the Cottonwood, viz: on Dutch Charley's creek, T. 108, R. 37; also on a branch of the Watonwan creek, T. 107, R. 34. At the former place it is now quarried, and is about to be at the latter. These places, however, have not been visited, though the characters of this quartzyte are so striking that the most unskilled observer could not fail to identify the stone. At

Redstone the beds are tilted at an angle of 35 to 40 degrees toward the north, showing their jagged edges which stick out along the north bank of the river. The exposed rock rises, a short distance north from the river banks, to a hight of 150 to 250 feet above the lowest exposed beds. In these bald, lichen-covered knobs the dip is maintained to the north at the same angle, making as much as 350 feet of stratification exposed. The surface of these knobs, and in general the surface exposure of the whole, is much more indurated and quartzitic than those lower beds that have been opened by quarrying and by the cutting for the railroad grade. It appears as if the greatest metamorphism had taken place over the surface, the lowest strata seen being more perfectly bedded and thinner, as well as argillaceous and wave-marked. The whole is of a reddish color, varying from brick-red in the lower beds, to a dark-red or purplish hue, in the highly metamorphosed portions. It sometimes shows a finely pebbly structure, and some small spots of a softer texture, which on fracture have some appearance of a greenish impure chert, or of a serpentinous or epidotic composition. These greenish spots are closely impacted in, or chemically united with the mass, as if derived from it. Other parts are more plainly a sandstone, much less glassy on fracture, showing all the characters of the *Potsdam sandstone*, as recognized in the lake Superior district. The following characters indicate the *Potsdam* age of this outcrop of red quartzyte.

1. Its red color, spotted with lighter color, even to cream color.
2. Ripple marks and mud cracks.
3. Worm-marks and fucoids.
4. Thin laminæ of shale separating the beds.
5. The very observable and regular bedding.
6. The impossibility of setting any limit between the evidently sandy and sedimentary portions and the quartzitic and metamorphosed portions. They pass one into the other in the distance of twenty feet.
7. The highly inclined position of the strata.
8. Its *arenaceous* character, taken as a whole, in distinction from the talcose and slaty, or the hornblendic and the micaceous nature of the *Huronian*.

A singular phenomenon was observed on these knobs, indicating the recent activity of volcanic forces. About sixty rods north from the railroad cut the superficial heavy quartzitic beds are tossed up on their edges in opposite directions, over a space of a couple of square rods, some blocks of ten feet long and four or five feet thick, standing exactly on their edges near the point of outburst. These pieces are all lichenous and weathered, indicative of the great age of their exposure in that condition. The whole place looks very much as the tilted beds in a quarry immediately after the discharge of a blast of gunpowder. In the center of the place where the beds are most disturbed and broken fissures and openings in the deeper seated strata may be seen, while one large opening descends down nearly perpendicularly into the rock. The positions of these loose pieces which are undeniably torn from the beds near where they lie, indicate the operation of some powerful subterranean force since that part of the state was subjected to the levelling process of glacier ice.

The *Lingula shale*, at the falls of the St. Croix river, is believed to hold a place stratigraphically above the sandstone at New Ulm, although at that place a trap outburst entirely screens the actual superposition from observation. These shale beds there abut conspicuously and almost horizontally against the trap rock which rises on nearly all sides to the hight of two or three hundred feet. At the village of St. Croix Falls a little creek enters the river at the foot of Georgia street. Just as it joins the river it passes over six or eight feet of green shale filled with *Lingulæ* and *Orbiculæ*, of which there seem to be several species. The shale is extremely rusty with iron in all crevices and partition planes, owing probably to the oxidation, by the running water, of the fine crystals of pyrites, with which much of the shale is crowded. After an obscured interval of several feet, believed to be occupied by this shale, at a point further up the creek, the water passes over about ten inches of coarse, rusty sandstone. Still further up this creek probably similar shale underlies the immediate surface. Yet the hills of trap rock rise suddenly within a quarter of a mile of the river, to the hight of over 150 feet. Further up the river, other creeks, entering from the east, expose the same shale along their sides, or in their beds. At one point the immediate bank of the St. Croix river shows, at the village of St. Croix Falls, a thickness of 49 ft. 8 in. of horizontal bedding, measured by Locke's level. The dry, weathered surface of this bluff has an ashen color, yet exudes a substance which on becoming dry is yellow and has much the taste of alum. There are also interlaminated thin layers of arenaceous shale or sandstone, more enduring. These, lying in fragments at the foot of the bluff, show surfaces that are almost completely covered with the broken or entire valves of fossil *Lingulæ* and *Orbiculæ.* These fossils pervade the whole thickness of this shale, so far as here seen, and they seem to have gathered in unwonted abundance in the isolated depressions or basins of the original trap-rock surface. Occasional rude septaria of impure blue limestone also contain, but in less quantities, the same fossil bivalves.

Section at Winona, in Winona county.

In ascending order the next section observed is that of the bluffs at Winona. It includes also a part of the *Lower Magnesian limestone.* It shows the following stratification in descending order:

No. 1.—Slope from the summit to the brink of Observatory bluff (character of rock unknown)		20 ft.
No. 2.—Arenaceous breccia, or conglomerate, belonging to the *Lower Magnesian limestone,* with considerable calcareous matter, especially in the form of patches of calc-spar and some very hard, gray limestone, which is often variegated in colors of red, greenish and pink. It contains also chert and colored flint; but the flint seems to be united with the matrix as if produced by chemical secretion like the calcite. This rock forms the bold buttresses which in many places round out the summits of the bluffs and form their prominent angles, as at Castle Rock, on the Wisconsin side, and on Observatory bluff opposite the normal school. At the railroad cuts, above Stockton, it stands out in isolated pinnacles and towers. It has the outward aspect of a rough, cavernous and concretionary breccia		35 ft.
No. 3—Heavy, regular beds of *Lower Magnesian limestone.* These layers are of a cream color, hard and enduring, and somewhat vesicular, but very extensively wrought for building, Of these beds 99 ft. 4½ in. are seen in the singular outlier known as *sugar loaf*		145 ft. 6 in.
No. 4.—Interlaminations of limestone with sandstone, belonging to the *St. Croix sandstone.* The details of the stratification here are as follows, in descending order:		
(a.)—Homogeneous, incoherent, white sandstone, very similar to the *St. Peter sandstone*	2 ft.	
(b.)—Hard sandstone, with considerable calcareous matter, having much the aspect of the overlying limestone with masses of common calc-spar	8 ft.	
(c.)—Friable sandstone, white.	2 ft.	
(d.)—Same as (b)	5 ft.	
(e.)—Loose, sandy shale, with fragments of light green shale in scales	1 ft. 6 in.	
(f.)—Same as (b)	3 ft.	
(g.)—Same as (a)	1 ft.	

(h.)—Same as (b), almost a pure and crystalline dolomite	6 ft.	
(i.)—Same as (a), very coarse grains of rounded sand, consisting of purely white quartz, with lenticular beds and masses of limestone	10 ft.	
(j.)—Same as (i), but more calcareous and projecting	20 ft.	
(k.)—Sandstone; massive, with little or no calcareous matter	12 ft.	
(l.)—Calcareous layers, and thin sand layers alternating as above, the greater portion being sand, aggregating about	55 ft.	
These alternations make up (e) and (f) of Owen's general section (see p. 73)		125 ft.
No. 5.—Massive mural sandstone, passing below a talus, seen		20 ft.
No. 6.—Interval, unobserved, hid by talus (covering (d) of Dr. Owen's general section)		226 ft. 3½ in
No. 7.—Hard, massive, ferruginous sandstone, containing *Lingula* ((c) of Dr. Owen's general section?) This is seen near the base of the escarpment, nearly a mile above Observatory bluff, seen		8 ft.
No. 8.—Sloping talus, to the level of Winona lake		15 ft.
Total hight of bluffs		594 ft. 9½ in.

Although other sections covering more or less of the *Potsdam* and *St. Croix* sandstones have been taken at different places, yet nothing has been observed throwing additional light on the relations of these two formations, and they are withheld till the proper time for reports on detailed work by counties.

(d.) *Fossils of the St. Croix and Potsdam sandstones.*

It has already been stated that the only fossils found in these sandstones pertain to the upper or St. Croix, and that in the lower which is more probably the real equivalent of the *Potsdam sandstone* of New York, no well defined fossil remains have yet been discovered in the state of Minnesota. The obscure fucoids and worm-marks have indeed been seen; but their real origin may be regarded as yet undetermined. For a list of fossils found in the the St. Croix beds, in the state of Minnesota, and enumerated by Dr. Owen, the reader may consult a former page entitled "preliminary considerations."

(e.) *Economical value of the St. Croix and Potsdam sandstones.*

The *Potsdam sandstone*, in the vicinity of lake Superior where invaded by the disturbance of trap outbursts, is known as the most highly cupriferous rock in the United States. This is not because the rock itself in all places is liable to contain copper, but is owing to the agency of igneous and perhaps to other metamorphic forces. It is also confined to the lower portion of the formation, and is accompanied with the various forms of volcanic rock and conglomerate. What amount of copper it may carry in the northern part of the state of Minnesota is entirely unknown. As it occupies a considerable area where the beds are known to have been highly tilted from a horizontal position, it is not unreasonable to suppose that copper in considerable quantities may yet be found. The Potsdam has also very often supplied a stone for building purposes of a very superior quality. The lake Superior "brown sandstone" is from rocks of this age. It is believed that the use of sandstone in important structures is to become much more prevalent than formerly, and any available outcrop of this rock ought to be fully proved for stone of this kind. The nearest and most accessible exposure of this kind for the markets of central and southern Minnesota is that at Redstone, near New Ulm. As it is reached directly by railroad, it is safe to say the time is not far distant when the markets of the state will be able to furnish stone from this vicinity of a quality equal to any found in the Northwest. It will also supply a vast extent of country in northern Iowa which is largely destitute of stone suitable for purposes of construction.

Some portions of the *St. Croix sandstone* have been quarried for building purposes, and at Taylor's Falls it has been used in one or two business blocks. It is of rather coarse grain and friable on first quarrying, but the weather operates to harden it in a few months. It is of a lighter, pleasanter color than the *Potsdam*. Except for the manufacture of glass, for which much of the light sandstones of the St. Croix beds is suitable, and favorably exposed along the Mississippi river,* it is not known that there is any other important use to which these formations may be put. Some of the clays, especially those stained with iron, may be made useful for pigments, and the bed of red *catlinite*, used formerly by the Indians in Pipestone county, takes a polish which will render it valuable for small ornaments.

*At Red Wing Mr. Pascal Smith so utilizes this formation, shipping it by barges down the Mississippi to points in Illinois.

3. THE LOWER MAGNESIAN LIMESTONE.

(a.) *Its area.*

Beginning at the southeastern corner of the state where this limestone forms the summits of the bluffs of the Mississippi and supports the high table-land that extends westward frôm the river, this formation occupies a belt of irregular width along the west side of that river to a point a little above Hastings, where its western limit crosses the Mississippi. The eastern edge of this belt runs along the east side of the Mississippi, including considerable of the state of Wisconsin. Hence it underlies the most of Houston county, the northeastern part of Fillmore, the eastern half of Winona, nearly the whole of Wabasha, and the eastern portions of Goodhue and Dakota. North of the Mississippi this belt curves more to the west, bringing its eastern margin across the St. Croix river a few miles below Franconia. Passing westward this limestone underlies the northern and eastern portions of Washington county, the central portions of Anoka, Hennepin and Carver, the most of Scott and Le Sueur, the eastern portions of Sibley and Nicollet, the central portions of Blue Earth and Martin and the southern portions of Jackson and Nobles. In the northwestern part of the state an area is supposed also to be underlain immediately by this limestone, but its limits are entirely conjectural, so far as they are expressed on the accompanying preliminary map. The same is true in respect to the boundaries of this limestone in the southwestern part of the state.

(b.) *Its general lithological characters.*

The eastern name of this limestone is *Calciferous sandrock*, so named from the intimate mixture of dolomitic and arenaceous ingredients. In Minnesota, however, a large proportion of this member of the Lower Silurian is a truly magnesian limestone, and almost free from sand. In some places heavy and continuous layers of white sand are found between equally heavy and persistent layers of limestone; while throughout the whole thickness of the formation the uniformity of the bedding is liable to interruption by the inexplicable occurrence of isolated masses of breccia, or cavernous conglomerate, in which the arenaceous and calcareous qualities are intimately and confusedly mixed. The lower beds are often abundantly interstratified with and broken by more or less continuous bands of chert. Distinctly oolitic characters also sometimes prevail. Its color is light, varying from a cream-color or light-buff, to a pinkish salmon. While much, even of the most evenly bedded portions of this limestone, is somewhat vesicular or shows spar-lined cavities, its general firmness is very great, and it forms the prominent angles to the summits of the bluffs on either side of the Mississippi below the confluence of the St. Croix. These even and heavy layers are those usually quarried for building-stone, while the less regular and concretionary parts are better adapted to lime-making, both from the greater ease with which the beds may be removed and their comparative freedom from sandy and clayey impurities.

The following sections have been taken from exposures of this limestone, in addition to that given in connection with the underlying sandstone, at Winona (p. 78), and will further elucidate the lithological characters of the formation.

Section at Quincy, in Olmsted county.

Taken near the dam, in descending order.

No. 1.—*Lower Magnesian limestone;* quite arenaceous, falling out in huge masses which are rough, distorted in their crude bedding, and unmanageable as a quarry-stone; showing much calc-spar. Limestone and sandstone are mingled with occasional strips of a light-green shale. In general the face presents the appearance of an alternation of horizontal layers of thin and more shaly beds, with heavy, coarse and rough limestone beds. Some green shale layers alternate with dark umber-colored (ochreous) shale, neither being more than two inches thick. They are tortuous and not continuous. This phase appears like the tops of the bluffs at Winona, but is probably at a considerably higher horizon	30 ft.
No. 2.—Persistent, white sandstone or granular quartzite, seen	10 ft.
Total exposure	40 ft.

Section at Shakopee, in Scott county.

The quarries at Shakopee for lime-burning expose about twenty-five feet of stratification, though the bedding is much confused and almost obliterated by chemical and other metamorphic agencies. The stone is very rough and very often a true breccia. It is somewhat arenaceous, and also argillaceous. Some small, shapeless cavities are filled with a greenish shale, which, if indurated, would be like some flinty spots often seen in the same formation, as at Winona. Some of this shale is so hard as to have conchoidal fracture, and some is so soft as to be like wax or putty in the fingers. It varies through different shades of green and blue. It seems to be intimately blended in texture with, and insensibly passes into, the compact limestone of the most fine-grained portions of the quarry. It is not a common ingredient. Some other cavities are lined with incrustations of mammillated and drusy quartz. Exposed about........................ 25 ft.

Section at Mankato, in Blue Earth county.

(Quarry of Maxfield and Sons: in descending order: gentle dip N. E.)

No. 1.—Porous magnesian limestone, not used	4 to 6 ft.
No. 2.—Coarse, friable sandstone	2 to 4 ft.
No. 3.—Magnesian limestone, burned for lime	2 ft.
No. 4.—Calciferous sandstone, in heavy beds, of various grain and texture, sometimes mottled, quarried for building	30 ft.
No. 5.—Shale, arenaceous and mottled with red	3 ft.
No. 6.—Calciferous sandstone, used as a cut-stone, for sills and fronts.	4 ft.
No. 7.—Rough and irregular sandstone	12 ft.
Total exposure	61 ft.

(No. 7 here is probably the upper portion of the *St. Croix sandstone*. The thickness of the *Lower Magnesian* is at least 230 feet.)

(c.) *Fossils of the Lower Magnesian limestone.*

This great dolomite is comparatively meager in fossil contents. It affords a small number (*three* according to Dr. Shumard) of species of trilobites, and a few of bivalve and univalve molluscs. Of these the most characteristic are *Dikelocephalus,* and other trilobites "allied to the family *Olenidæ*" (Shumard); a handsome little *Lingula*, "of an ovate shape, with fine concentric striæ, not distinguishable from *Lingula Dacotaensis*" (Shumard); also another species of *Lingula* much larger than *L. Dacotaensis*; an unnamed species of *Pleurotomaria* (?), an unknown species of *Orthis Terebratula*. Besides these the most frequent fossil, perhaps, and throughout at least the upper portion of the formation, is a species of *Euomphalus* (*Ophileta?*) which is apparently the same that Dr. Owen has described and named *Straparollus Minnesotensis*.* The observations of the present survey have only disclosed a gasteropod

*On page 484 of Owen's final report, Dr. Shumard describes this fossil as found in F. 1. Yet Dr. Owen in his description [p. 581], and on plate II assigns it to the *Lower Magnesian*. A similar contradiction occurs in the double assignment of *Pleurotomaria muralis*. It is referred from the same locality both to F. 2, and F. 3, so constantly that it cannot be attributed to typographical oversight.

fossil, probably the same *Euomphalus*, in the upper portion of the formation, seen in the bed of the Zumbro, at Rochester, near the Bradley House; and a species of *Lingula* answering the characters of *L. Dacotaensis*, in the same stone where quarried by Messrs. Maxfield and Sons, at Mankato.

In Iowa crinoidal remains are found in the *Lower Magnesian*. In Wisconsin near Madison a *Dikelocephalus* trilobite was found in the drift, supposed to be from the *Lower Magnesian*, and Prof. Hall also reports various indistinct remains of *Orthoceratites*. In western Canada the *Lower Magnesian* exhibits a more abundant fauna, including different genera of trilobites, orthoceratites, gasteropods, and brachiopods. The great "Quebec group" which, in eastern Canada, is supposed to include the *Lower Magnesian* of the Northwest, unfolds an entirely new and wondrously rich assemblage of Silurian fossils.

(d.) *Economical value of the Lower Magnesian.*

The value of this limestone is greatly enhanced by its stratigraphical position. It is not only the lowest in the geological series of the state, but it is separated from the next higher by a considerable thickness of friable sandstone. Therefore it must serve all the uses to which limestone may be put, throughout the area of the granitic and metamorphic rocks,* and also throughout the adjoining belts of the *Potsdam* and the *St. Croix*, and the *St. Peter* sandstones on either side.

As its name indicates, it is not a pure limestone, but a dolomite, or magnesian limestone. It usually contains about one equivalent of carbonate of lime, and one of carbonate of magnesia, with some insoluble silicates, and traces of alumina and iron, the largest per cent. being made up of carbonate of lime. It was formerly believed that a dolomitic limestone was not adapted to lime-burning. The pure limestones, or those that comprise about ninety per cent. of carbonate of lime were eagerly sought for the strength and quickness of the lime they afford. Such is the character of most of the first twenty feet of the *Trenton limestone*, which lies above the *St. Peter sandstone.* It has more recently been found, however, that the magnesian limestones, to which class belong most of those of

*No notice is here taken of *metamorphic limestones*, some of which may occur in Minnesota. They furnish the *marbles* of the New England states.

Upper Silurian age in the Northwest, as well as the *Lower Magnesian* and the *Galena* of the Lower Silurian, afford a quicklime which, although less hot in slacking, and slower in setting, is on the other hand more cheaply burned and better adapted to the uses of common mortar.

"The properties of these limestones are very different. Those of the first class require to be submitted to a higher temperature in 'burning' than the second. They slake promptly and thoroughly and in the operation evolve a great degree of heat. From this last fact they are termed 'hot' or 'fiery' limes. They 'set' or harden so soon that but two or three bricks can be laid with one spreading of mortar, and walls that are made of them have a tendency to 'chip-crack.' It is quite likely that this last named property can be attributed, in some degree, to the silica and alumina that they contain.

The second class contains those limes that are called 'cool.' They do not give out as much heat in slaking as the limes of the first class, nor do they 'set' as soon. From five to twenty bricks can be laid with a single spreading of mortar, and in plastering a corresponding advantage can be obtained.

On purely practical grounds the builders of southwestern Ohio have come to recognize the greater desirability of the limes of the last named class, and none others can now find market in the cities and towns of this portion of the state." [PROF. EDWARD ORTON, on the geology of Montgomery county, in the first report of progress of the geological survey of Ohio, for 1869].

The lime made from the *Lower Magnesian* in Minnesota is, so far as observed, of a very dark color. It is distinguished in some places as "black lime," in comparison with that burned from calcareous tufa, which is called "white lime." In other places it is known as "leather-colored" lime. Yet even where the bulk of the lime produced is of a dark color, some inconsiderable spots and streaks are almost as white as lime made from any other formation.

The lime made at Shakopee, in Scott county, is exceedingly dark, and is commonly known as leather-colored. It has not the purplish or ashen tint of some dark, Ohio limes from the Hamilton limestone, but an ochreous or umber color. It is also specked and sometimes streaked with whitish spots or with shades of lighter brown, and in slacking it takes the color of rich cream.

At the kiln of Mr. Isaac Lincoln, lime sells at 75 cents per barrel of 225 pounds, on the ground. Last year 16,000 barrels were shipped, or an average of 1,300 barrels per month. The monthly production sometimes reaches 2,700 barrels. The markets are mostly St. Paul and Minneapolis. Mr. Lincoln burns from four to five cords of mixed wood to each hundred barrels, and uses a constant kiln of a patent unknown.

The other kiln at Shakopee is owned by Mr. Baptiste Contre. Lime here sells mostly at St. Paul and Minneapolis at 75 cents per barrel. The monthly production is from 1,200 to 1,700 barrels, consuming four or five cords (mostly *four* cords) of mixed wood per hundred barrels. The kiln is similar to that of Mr. Lincoln. At Louisville, four miles further up the Minnesota valley, are two other limekilns employed in burning the *Lower Magnesian*.

At Mankato, in Blue Earth county, the quarry of Messrs. Maxfield and Son supplies both quicklime and building stone. The former is delivered at the depot at 80 cents per barrel of 225 pounds. Twenty cords of mixed wood burn three hundred barrels.

Stone from the quarry of Messrs. Maxfield and Son, at Mankato, has been used in the construction of the Catholic church at that place. The foundation and all dressed stone in the Second Normal School building are from the same quarry. The foundation and dressed stone in the City bank and in Harmonia hall, as well as the entire structure of Higgins hall, and the fronts of several business blocks, at Mankato, are from the same quarry.

At Kasota, in Le Sueur county, the *Lower Magnesian* is considerably wrought, and is finding market at Minneapolis and St. Paul. Quarries here are owned by Reuben Buttars, J. W. Babcock, and by Downs Brothers. The stone itself is handsomely tinted with pink; and for its beauty, its regularity of bedding which is sometimes nearly two feet in thickness, and its homogeneous texture which renders it easy to shape into all forms, it is adapted to ornamental work as well as heavy masonry. It is cut, as at Mankato, into posts, sills, caps and water-tables. For its adaptability to all uses it is worthy of being ranked with the Waverly sandstone, and it is more enduring even than that, under the action of atmospheric changes, owing to the more general and abundant dissemination of the calcareous cement; while its variegated coloring, and its more lively expression make it preferable in many kinds of work. It is used in the north and south wings of the state lunatic asylum at St. Peter, and the central portion of the building, when completed, will contain it. The Episcopal church, and the old Asylum building are also constructed from it. The new Baptist church at St. Paul is being made from the Kasota stone. In old structures where it has been exposed for a number of years to the disintegrating action of the elements, it shows as sound and hard as ever. It even becomes harder on exposure, as the quarry water dries out.

At St. Peter, in Nicollet county, a quarry owned by the Asylum farm affords a stone of a lighter color, but otherwise very similar to that from Kasota, being also in the *Lower Magnesian.*

At Red Wing, in Goodhue county, the quarries near the top of La Grange, or "barn bluff," supplied from the *Lower Magnesian* the stone put in the railroad-bridge over the Mississippi at Hastings, and also that used in the Episcopal church at Red Wing.

At Winona, in Winona county, valuable quarries in this formation have been opened in the "sugar loaf," by Mr. Toms, and in the bluff next west of "sugar loaf" by Mr. James Burke. These quarries supplied the trimmings and all cut-stone used in the normal school at that place.

At Stillwater, in Washington county, the *Lower Magnesian* is extensively used for the most important structures. Some of it is quite close-grained, and without pores, making a fine cut-stone of a light cream-color. Some of it, from the same quarry, is also very rough and porous, and of a darker color. That, however, which is rough and porous is as enduring as that which is compact. Indeed the porous masses are apt to be more lasting and in heavier beds than the close-grained. This stone has been put into the public school-house at Stillwater, and as trimmings in many houses built of brick. The state prison at the same place is built of it. The court house is of red brick (made near Stillwater), the trimmings being of the *Lower Magnesian* quarried at Stillwater, and of the blue flagging, from the *Trenton* quarried at St. Paul. The steps in front and the walls at the ends of the steps are of the *Lower Magnesian*, while the coping, sills, lintels and water-tables are of the darker colored *Trenton.* Several churches at Stillwater are made of the *Lower Magnesian* with *Trenton* blue flags from St. Paul, for sills, caps and water-tables. This combination of colors gives the structure a very attractive *ensemble*, but it is at the cost of durability. It is a great mistake to place these blue flags in such exposed parts of important buildings. They are much more destructible than the *Lower Magnesian*, and will fall out in chips and thin shaly partings long before the weather has any effect on the *Lower Magnesian* of the main walls.

4. THE ST. PETER SANDSTONE.

(a.) *Its area.*

The incoherency of this sandstone renders a definition of its area very difficult. It is placed between two important limestones of the Lower Silurian, both of which endure the erosion of ice and water and the disintegrating action of atmospheric forces with greater persistence than the sandstone itself. The underlying *Lower Magnesian* is apt, in the southeastern portion of the state, to stretch out for several miles over a low flat, its upper surface forming the basis. But as it gradually passes, owing to a gentle dip, below the surface, occasional isolated mounds rising about 125 feet above the general level are seen by the traveler. These become more and more frequent and at last coalesce in the direction of the dip, so as to form a continuous flat topped shoulder or bench, like the *mesas* of New Mexico, on which the same features of surface and soil prevail as on the lower flat formed by the *Lower Magnesian.* On examination of these precipitous ascents from the lower to the higher prairie, they are found to consist of the *St. Peter sandstone*, capped with the first fifteen or twenty feet of the overlying *Trenton limestone.* As this protecting limestone has a thickness of about 160 feet it also furnishes a further ascent, but one that is not marked off by so distinct bench-lines. Owing to the occurrence of considerable shale and easily erosible beds at about the horizon of twenty feet above the *St. Peter sandstone*, it happens that often over a wide belt only these twenty feet of the *Trenton limestone* are preserved. They form the brow of the hill that separates the lower from the upper prairie, already mentioned, and have hitherto been more fully examined than any other portion of the *Trenton* within the limits of Minnesota. Hence the area of the *St. Peter sandstone* is actually reduced, where the boundaries of the formations are easily seen, to the narrow belt forming the slopes between the upper and lower prairies. These slopes are generally turf-covered. The delineation of the area of the *St. Peter* is further complicated by the action of streams. These often cut their channels through the overlying twenty feet of *Trenton*, and into the *St. Peter* some miles above their debouchure on the actual area of the *St. Peter;* and near their entrance upon the area of that sandstone their channels are widened out enormously, the enclosing bluffs receding rapidly from the immediate river banks. In addition to these irregularities of outline, there are not infrequently detached areas within the general limit of the *Trenton limestone* where the protecting beds of the Trenton are broken down and removed by some force not now in operation, forming, in the *St. Peter*, basin-shaped depressions, the bottoms of which are on the *Lower Magnesian*, the surrounding bluffs being made up of the *St. Peter sandstone*, and the high prairie stretching out in all directions being underlain by the Trenton. Such *arroya* valleys, which are now without any visible surface drainage, are sometimes united by wide mouths with other, larger valleys that present a similar topography. Indeed the whole belt of country underlain by the outrunning *Trenton* and the *St. Peter sandstone* is made up of a network of little valleys many of which coalesce and become tributaries to larger drainage valleys, and some of which appear simply as isolated depressions. It is a tract of rolling country of great beauty of natural scenery, and most perfectly exemplifies the effect of geological causes on the topography and agricultural character of the state.

This belt of rolling land immediately dependent on the underlying rock enters the state from Iowa in Houston county, in a general northwesterly direction. It embraces the western portions of Houston and Winona, the eastern portions of Fillmore and Olmsted, and some portions of Wabasha, Goodhue and Dakota counties. Further northwest, in the counties of Ramsey, Hennepin and Anoka, the area of the *St. Peter sandstone* is heavily covered by drift, and its presence would not be known except for its exposures in the Mississippi bluffs, and the known limits of adjoining formations. From Dakota county the *St. Peter sandstone* extends theoretically southwestwardly in a belt of 6 to 10 miles wide, passing through the central part of Rice county, touching the northwest corners of Waseca and Faribault, and leaving the state again in Martin county in a southwesterly direction. On the other side of the granitoid axis, in the northwestern portion of the state, a belt of this sandstone is supposed to exist, and is conjecturally laid off on the preliminary map accompany this report.

(b.) *Lithological characters of the St. Peter sandstone.*

The outward, and also the chemical characters of this sandstone, in Minnesota, are, so far as seen, remarkably constant and simple. It is white, "saccharoidal," friable, non-fossiliferous, and consists almost entirely of pure quartz sand. It contains not enough lime to act as cement, and hence can almost everywhere be excavated even with the fingers. On exposed surfaces, as along the bluffs of the Mississippi, where dripping water passes over it, the grains become more bound together by deposition of carbonate of lime and iron oxide, and its delicate whiteness is lost. Indeed, wherever water in the smallest quantity is allowed to trickle through it, a deposit of iron oxide is invariably seen, since rarely, if ever, is any surface water found entirely free from that impurity.

A number of sections have been observed of this formation, but the characters seem to be invariable throughout. Its thickness is about 125 feet, and it is the immediate cause of a great many waterfalls. The falls of St. Anthony are caused by the passage of the river from the *Trenton limestone* onto the *St. Peter*. The latter, rapidly worn away by the current, leaves the projecting limestone to fall down in heavy blocks as fast as it becomes too feeble to support further its own weight. This protecting cap of limestone extends but a few rods above the present brink of the falls, and it was a thoughtless tunneling underneath, in the soft *St. Peter*, that admitted the water of the Mississippi a few years since, above the limit of the limestone, thus endangering the existence of the falls themselves. They would soon have been reduced to a foaming rapid, which eventually would have entirely disappeared. Vigorous measures were speedily adopted by the citizens of Minneapolis, tardily aided by the U. S. government, to secure the water-power, and by carefully shutting off the water from the tunnel, and "aproning" the waterfall itself with heavy timbers and planking, as well as laying over the river bottom above the falls a thickness of gravel and clay to prevent a further erosion, it is believed that desirable object has been effectually secured. The falls of Minnehaha are also caused by the same conjunction of a drainage stream with the boundary line separating the *St. Peter* from the *Trenton limestone.* This unique and legendary little gem of a waterfall has a perpendicular descent of 52 ft. 10½ inches from the brink of the overhanging limestone to the surface of still water below. About twenty-five feet of that distance are taken up with the *St. Peter sandstone*. Numerous little cascades of great beauty enter the Mississippi in the vicinity of St. Paul and Minneapolis. As these are projected over the limestone rim which borders the Mississippi bluffs, they are thrown in more or less entire sheets of clear water into the river below. Such are known as *the fawn's leap*, *the bridal veil*, *the silver cascade* and *the silver thread*.

The singular pillar in Dakota county, known as *Castle Rock*, consists of the *St. Peter sandstone*. It stands on the arch of the local anticlinal axis from which the beds dip gently both toward the north and toward the south, and is an outlier from which most of the formation has been removed over an area of some miles about. Its form is that of a somewhat regular right prism, or parallelopipedon, elongated north and south, supporting on its northern end a pinnacle of bedded sandstone about four feet in diameter at the base, which rises above the general mass 19 ft. and 3 inches. A view from the west shows of rock 44 feet and 9 inches, rising above the general surface of the sandy mound on which it stands. Rock can be seen on the east side about 20 feet lower than on the west. A depression along the east side of the outlier is 26 feet below the lowest rock visible. From the bottom of this depression to the top of the tower is 70 feet 1¾ inches. The irregularly ascending base visible from the west is 11 ft. 6 in. The perpendicular sides of the general mass of the rock are 14 ft., and the tower is 19 ft. 3 in. Near the base of the tower is a somewhat argillaceous layer, or one less firmly cemented, of a few inches, which weathers away faster than the rest, making the diameter there considerably less than above. Hence the tower has a threatening aspect, and the first impression of the beholder is the certainty that the first severe blast of wind will throw it from its place. The mass of the whole is separated perpendicularly by a number of divisional planes that also may be seen entering the rock below the castle. These pass in a direction N. E. and S. W. and have so aided the attacks of the elements and invited the ambitious but sacrilegious carvings of visitors that a hole has been made through the body of the rock.

(c.) *Economical value of the St. Peter sandstone.*

The St. Peter furnishes inexhaustible quantities of the purest quartz sand. Its easy excavation renders it obtainable for common mortar and for glass-making. Its exposures along the Mississippi bluffs at and below St. Paul invite its use in the manufacture of flint glass of which it is known to make a very superior article. At Minneapolis the close proximity of waste fuel from the lumber mills, ample water-power and favorable exposures of this formation ought long ago to have been improved in the establishment of a glass manufactory. At the present time Minnesota furnishes from the *St. Croix sandstone* a sand believed to be inferior to that from the *St. Peter*, which, taken to a neighboring state, supplies the glass that returns to her citizens encumbered with a double freightage. This process ought to be arrested by the utilization within our own territory of this vast resource, peculiar largely to Minnesota. At present this sandstone is not known to be used for any purpose within the state except for mortar for the local markets and as an engraving board for idle boys. Sometimes beer vaults are made in it along the river bluffs, and sewers for the drainage of the cities of St. Paul and Minneapolis are excavated through it, the overlying limestone affording a secure roof.

5. THE TRENTON LIMESTONE.

(a.) *Preliminary considerations.*

This term is here applied to that series of limestones and shales that fill up the interval between the well marked horizons of the top of the *St. Peter sandstone*, and the bottom of the *Galena limestone*. It is quite likely that when this series of beds is fully examined differences may be ascertained warranting its separation under two or more names, but at the present time the characters of its whole thickness, which amounts to nearly 160 feet, are so little known that it has not been possible to establish any constant paleontological or lithological horizons. Dr. Owen, in his final report on Wisconsin, Iowa and Minnesota, mentions only the lowest 34 feet of these limestones, owing to the more frequent exposure, as has been mentioned already, of that portion of the *Trenton*. Those 34 feet Dr. B. F. Shumard separates into the following parts:

1. Upper, or St. Peter shell limestone, F. 3. c.................... 6 feet.
2. Non-fossiliferous bed, F. 3. b.................................. 5 feet.
3. Lower shell limestone, F. 3. a.................................. 23 feet.

The geologists of Wisconsin have described these limestones under the terms "buff limestone" and "blue limestone," the former lying below the latter, following the preliminary sub-division of Dr. Owen, published in a report of progress in 1840. They there have a thickness of 70 to 90 feet.* These distinctions have not yet been observed in Minnesota, and the aggregate thickness of the beds is considerably greater. The early geologists of Iowa gave the term *Trenton limestone* to all the layers between the *St. Peter* and the *Galena* and assign them an aggregate thickness of 100 feet.† Dr. C. A. White, also, of the recent geological survey of Iowa, embraces these shales and limestones under the single term *Trenton limestone*, but ascertains their thickness to be about 200 feet.‡ Mr. Worthen, in Illinois, embraces the *Galena*, the *Blue* and the *Buff* limestones under the term of *Trenton Group*, giving the latter two a united thickness of 70 to 105 feet, the *Galena* overlying, having a thickness of 250 to 300 feet.§

(b.) *Area of the Trenton limestone.*

The *Trenton* occupies a belt of country lying just within that of the *St. Peter*, in the southern part of the state, and conjecturally an area in the northwestern part of the state. The former may be described with considerable exactness. By reference to the description of the area of the *St. Peter* it will be seen that the line separating these two formations is very crooked, especially in the southeastern portion of the state, where the drift is light. The causes that operated to give this line such a winding direction, up and down hundreds of little valleys, seem to have pertained largely to pre-glacial time, and to have continued also into, and near the close of, the ice period,—or to have recurred, after a suspension, during the ice period with all their former activity. They seem to have been closely connected, perhaps identical, with those that exempted this region from the heavy covering of drift that prevails further west and north. At least, it is plain that the absence of the drift has allowed the freer action of the elements that slowly, but effectually disintegrate and remove rocky structures, causing those which are most enduring to stand out most prominently, af-

**Geological survey of Wisconsin*, 1861, vol. I.
†*Geology of Iowa*, 1858, vol. I. part I.
‡*Geology of Iowa*, 1870, vol. I.
§*Geological survey of Illinois*, vol. I.

fording shelter to those which retreat fastest from their attacks.

The western line of the *St. Peter* is the eastern line of the *Trenton*, in the southeastern portion of the state, and need not be further defined. The western line of the *Trenton*, in the same region, although less tortuous than the eastern, is still quite irregular, the overlying *Galena* comparing, in respect to relative endurance, to the *Trenton*, very much as the *Trenton* does to the *St. Peter*. It is impossible definitely to lay out this area until the various counties are examined in detail, but in general the area of the *Trenton* comprises a wide belt through the central portions of Fillmore, Olmsted and Goodhue counties, including three or four towns in the southwestern corner of Winona, and touching the southwest corner of Wabasha. This belt is then deflected westward through the counties of Rice, Blue Earth and Faribault, leaving the state probably in Martin county. Isolated areas occur in Dakota county, capping the *St. Peter sandstone*; and a large detached area of the lower portion of the *Trenton*, with a local dip toward the north, covers the northern portion of Dakota and much of Ramsey and Hennepin counties. This detached area gives location to the falls of St. Anthony. The area of *Trenton* in the northwestern portion of the state is laid off conjecturally, the only guide being the report of Prof. H. Y. Hind on the Assiniboine and Saskatchewan districts of British America, printed in 1859.

(c.) *Lithological characters of the Trenton limestone.*

In Minnesota, as far as seen, the *Trenton limestone* is abundantly associated with beds and laminations of green shale. The calcareous layers themselves are usually from one to four inches in thickness, but sometimes exceed a foot, while the beds of shale are apt to be massive and sometimes have a thickness of ten feet. The shale beds are often supplied with fragmentary fossils, and the layers of limestone are uniformly fossiliferous. The calcareous and argillaceous portions are also in some portions of the formation more closely interstratified; or the shale may be interwoven with the calcareous layers in such a way as to replace them at short intervals, the whole adhering strongly on fresh fracture, but on being weathered readily disintegrating. This is the aspect of some of the beds near the bottom of the formation which are used for building purposes at St. Paul and Minneapolis. The stone in this case has an attractive exterior on being dressed under the hammer, the variegations due to the alternating shaly and limy parts giving the face a clouded appearance, as of gray marble, without being susceptible of a uniform polish. Where protected from the weather the shale will endure, and act as a strong filling for the framework of calcareous matter for a long time; but under the vicissitudes of moisture and dryness and of freezing and thawing, it begins to crumble out in a few years. In other places the calcareous layers, even on the same horizon as at Minneapolis and St. Paul, are very much thicker and afford strong unyielding material for building. In this last case the calcareous layers are more strongly crystalline, but not vesicular. Many of them, especially when associated with considerable shale, are nearly made up of fragments of fossils, visible to the unaided eye, and doubtless the shale beds are also calcareous as well as sedimentary. The texture of the stone is close; yet some portions near the base, thought to be the beds denominated by Dr. Shumard "upper shell limestone," are often vesicular and of a light color. The natural color of the stone, on deep quarrying, is blue, but it is often faded to an ashen drab to the depth of several feet, depending on the ease with which water and air find access within. The porous layers are apt to be most faded. The long weathered surface is of a light buff color, or if iron be present in dripping water, or contained in the stone as pyrites so situated as to be oxidized, the color is sensibly deepened to a rusty yellow.

The effect of this formation on the topography of several counties in the southeastern portion of the state has been alluded to in connection with the same subject in treating of the *St. Peter sandstone.* Owing to the frequency of shaly interlaminations its outline, where the drift is light, is not so well defined in terraces as that of the overlying *Galena.* Its line of junction with the *St. Peter sandstone* is, indeed, very evident even in all its tortuosities, but its junction with the *Galena* is generally hid by a sloping, turf-covered talus of *debris*; and it is only at favorable places in the bluffs along the streams that a knowledge of that horizon can be obtained. The whole formation weathers away so evenly that where its effect on the topography is not brought out by drainage erosion or by the *Galena limestone* or the *St. Peter sandstone*, it produces nothing more than a gentle swell or evenly rounded ridge exposing none of the beds.

Sections have been observed covering all the beds of the *Trenton*

The best section of the *lower* and *upper shell beds*, of Dr. Shumard, is that taken at the falls of Minnehaha, although the same beds are seen well exposed at many places between St. Anthony's falls and St. Paul.

Section at the falls of Minnehaha, Hennepin county.

In descending order.

No. 1.—Beds 6 to 14 inches, very fossiliferous and sometimes vesicular. Contain *Leptœna deltoidea* in abundance, and *Strophmena alternata (?)*, also a *Cypricardites*. This is an important and marked horizon to which other sections may be referred. It forms the brink of the falls, but its best exposure is in a bluff a few rods below. Seen........ 9 ft.
No. 2.—Argillaceous limestone of a greenish color, weathering out conchoidally........ 2 ft.
No. 3—Arenaceous shale, weathering fine........ 2 ft.
No. 4.—Blue flagging, with considerable green shale. The principal building stone of Minneapolis and St. Paul is from this member. Great portions of this are made up solely of comminuted fossil remains showing crinoidal joints. It is of sedimentary rather than of chemical origin........13 ft. 6 in.
No. 5.—Green shale, about midway containing one layer of about two inches of limestone........ 3 ft. 8 in.
No. 6.—*St. Peter sandstone*, somewhat argillaceous, and of a greenish blue color........ 2 ft.
No. 7.—*St. Peter sandstone*, superficially stained and hardened by lime and iron........25 ft.

Total........ 57 ft. 2
Total of the *Trenton*........ 30 ft. 2 in

Section near the falls of St. Anthony, Hennepin county.

A quarter of a mile below the university. In descending order.

No. 1.—Limestone, mostly of a close grain and bright blue color, showing many fossils, principally of *Leptœna deltoidea*, but also containing cephalopods and gasteropods. The fossil remains are usually not fragmentary. They are apt to lie in sheets, making dark streaks horizontally separating the bedding. Under the weather this stone falls out in chips ½ to 2 inches thick and 4 to 8 inches across, which ring under a blow from the hammer. The surface weathers a rusty buff, the stone itself becoming a gray drab........ 11 ft.
No. 2.—Blue shale, crumbling out, the upper four feet somewhat bedded, the rest below massive, the whole occasionally showing patches or short sheets of fragments of brachiopods, &c., making the rock more calcareous and enduring........ 9 ft.
No. 3.—Blue flagging, quarried here and placed in the west wing of the university building. This stone is rather too argillaceous to be a reliable building material, yet is extensively used. Some parts of it are free from shale. Such beds furnish a firm and very enduring stone........ 15

No. 4.—Blue shale, parting conchoidally under the weather, seen....... 2 ft.
[No. 5.—St. Peter sandstone, to the water level 38 ft.]

Total of the *Trenton*........... .... 37 ft.

The total hight from the water's edge, at this quarry, to the summit of the drift bluff on which the university stands, measured by Locke's level, is 137 feet.

There is no visible dip here in the bedding, but at the falls of St. Anthony the dip is two or three degrees to the southeast.

At the point where the foregoing section was taken the *St. Peter sandstone* is tunneled artificially to the depth of nearly 200 feet, the excavation being ten or twelve feet in diameter, rudely dug out and arched. It was intended for a beer-vault.

Section at St. Charles, in Winona county.

At a quarry near St. Charles, half a mile south of the city, the lower portion of the *Trenton* appears as follows, in descending order:

No. 1.—Hard, crystalline, calcareous layers, ringing under the hammer, of a light drab color, without shale, fossiliferous........... .... 15 ft.
No. 2.—Bluish green shale, about.................................. 10 ft.
[No. 3.—*St. Peter sandstone*, seen 6 feet.]

Total *Trenton*...................... .... 25 ft.

At this place the dip is two or three degrees S. W. St. Charles sits on the top of the *Lower Magnesian limestone*, which is seen in a quarry a little N. E. of the city, and is nearly surrounded by bluffs formed by the *St. Peter sandstone*, capped with the lower portion of the *Trenton*. This exposure of the *Lower Magnesian* is along a little creek, the amount of bedding seen being about 16 feet.

Sections at Rochester, in Olmsted county.

At the "old Harmon quarry," from which the flouring-mill and the foundations for the new public-school house were built, the lower portion of the *Trenton* appears as follows, in descending order:

No. 1.—Green shale, seen... .... 4 ft.
[This is said by Mr. Hurlbut to be about 14 feet thick where it is all preserved.]
No. 2.—Hard, brittle limestone, in two beds, separated by about two inches of green shale. This is much like No. 1, of the foregoing

section at St. Charles. It has a drab color. A handsome *Strophomena* is the most characteristic fossil........................ 1 ft.
No. 3.—Alternations of shale and limestone........................ 1 ft.
No. 4.—Limestone of the same kind as No. 2, with some partings of shale, but sometimes quite blue instead of drab, seen...........10 ft.
No. 5.—Blue shaly limestone, more like the blue flagging quarried at Minneapolis. Not well exposed; amounts to about............ 6 in.

Total *Trenton* seen ....16 ft. 6 in.

At another point further west, on Mr. O. P. Whitcomb's land, the bed of green shale separating the foregoing *Trenton* from the *St. Peter sandstone*, or rather forming the base of the *Trenton*, may be seen in a weathered bluff, exposing a thickness of about ten feet, as at St. Charles. The quarry of Mr. O. P. Whitcomb, at Rochester, is made up as follows, in descending order:

No. 1.—Green shale, containing fragmentary crinoidal stems, *Chætetes* and various small brachiopods, among which may be distinguished a *Rhynchonella*. [Mr. Hurlbut thinks about 5 feet more are broken down from above, not now visible.] seen .... 10 ft.
No. 2.—Limestone, of a drab color and fine grain, in beds of about three inches, with much intervening shale in continuous layers.......... 3 ft.
No. 3.—Compact limestone, used in building, of a blue color, but comparatively free from shale.. 17 ft.
No. 4.—Green shale, lying on the *St. Peter sandstone*, not well exposed, seen.. 1 ft.

Total *Trenton* seen.. 32 ft.

From No. 2, above, have come some of the finest and largest specimens of cephalopods.

Section on Root river, in sec. 16, Pleasant Grove, Olmsted county.

At the point observed the section consists, in general, as follows, in descending order: Perpendicular escarpment showing generally a thin bedded and often shaly rock, the thin shale partitions being as thick as ½ or 1½ inches, about 37 feet. The descent then is irregular over beds of argillaceous limestone and shale mostly hid from view. Some of these shale beds are six and eight inches thick, and from them, where crumbling under the weather, fragments of fossils fall, such as *Chætetes* (principally), *Maclurea* and *Orthis*. The limestone weathers rough and thin-bedded, and shows *Receptaculites*. This interval includes about 47½ feet. There is then a broad shoulder, making up a talus covering, as disclosed, further down the river, a heavy bed of green shale, which overlies, near the water's edge, the limestone layers of the foregoing sections at Rochester, 42 feet. Total of beds supposed to be of the *Trenton*, 126½ feet. Combining this section with the observed thickness at Rochester, omitting the overlying shale bed (here embraced in a talus) the observed thickness of rocks of *Trenton* age amounts to 156½ feet against the 34 feet observed by Dr. Owen.

Sections at Mantorville, in Dodge county.

The Mantorville quarries show the horizon of the junction of the *Trenton* with overlying *Galena*. The same horizon is better exposed at Pettit's mill, one and a half miles below Mantorville, on sec. 22, T. 107, R. 16, along the middle branch of the Zumbro river. These sections are as follows:

1st. That of the quarry of Mr. Charles Ginsberg, in descending order:

No. 1.—[Loose fragments, 5 ft.]	
No. 2.—Heavy beds of vesicular, magnesian buff limestone........	8 ft.
No. 3.—Thin beds of the same, with a little shale................	4 ft.
No 4.—Heavy, buff, magnesian beds....	7 ft.
No. 5.—Thin, blue argillo-magnesian beds.......	10 ft.
No. 6.—Even-bedded magnesian limestone, the bedding of which weathers out from two to six inches, (poorly seen).......	5 ft.
Total seen...............	34 ft.

At this quarry the buff or cream colored stone shows a light blue color in deep quarrying.

2d. The quarry of Mr. Samuel Wilson, located near Mr. Ginsberg's, includes more of the *Galena*.

No. 1.—[Loose fragments, 4 ft.]		
No. 2.—Beds from six to twenty inches each, of vesicular, magnesian limestone, almost free from iron, fine for a "quarry stone"........................	30 ft.	10 in.
No. 3.—Thin, slaty, argillo-magnesian beds.....................	1 ft.	6 in.
No. 4.—Good, heavy beds of magnesian limestone, same as No. 1.	11 ft.	6 in.
No. 5.—Shaly and thinner beds, seen.......	5 ft.	
[NOTE.—Where these beds are weathered out, a white deposit is accumulated on the slope below, having much the taste of lime, yet may consist of alumina and lime. On the face of the rocks the coating is bitter and sour, tasting somewhat like Epsom salt.]		
No. 6.—Heavy magnesian layers, of a buff color, with considerable shale, same as Nos. 3, 4 and 5, of Ginsberg's quarry, but poorly seen, about	20 ft.	
Total seen...	68 ft.	10 in.

Section at Pettit's mill, sec. 22. T. 107, R. 16, Dodge Co.

No. 1.—Slope from the summit of the bluff (hid) estimated	40 ft.	
No. 2.—Magnesian layers, buff, much shattered	4 ft.	6 in.
No. 3.—Shale	2 ft.	6 in.
No. 4.—Good layers of vesicular, buff magnesian stone, with some argillaceous patches	11 ft.	
No. 5.—Argillo-magnesian limestone, weathering into rather thin beds	3 ft.	
No. 6.—Vesicular, buff, magnesian limestone. In one bed		10 in.
No. 7.—Shale and shaly limestone	2 ft.	2 in.
No. 8.—Beds of argillaceous limestone, each of about eight inches, separated by shale beds, each of about two inches	5 ft.	2 in.
[NOTE.—In No. 8 is found the coral *Receptaculites*.]		
No. 9.—Shale		4 in.
No. 10.—Vesicular limestone, argillo-magnesian. In one bed		9 in.
No. 11.—Shaly and calcareous beds (thin)		8 in.
No. 12.—Crystalline beds of a gray color, weathering buff, one bed	1 ft.	7 in.
No. 13.—Shale and shaly limestone	1 ft.	4 in.
No. 14.—Shale		8 in.
No. 15.—Argillo-magnesian limestone, some parts crystalline and calcareous only, in three beds	6 ft.	4 in
No. 16.—Shale		4 in.
No. 17.—Argillo-magnesian, one bed		10 in.
No. 18.—Shale	1 ft.	2 in.
No. 19.—Hard crystalline limestone, of a gray color, with some cavities and specimens of *Receptaculites*	2 ft.	2 in.
No. 20.—Shale		6 in.
No. 21.—Argillo-magnesian, one bed, showing *Chætetes* and fucoids of the *Trenton*	1 ft.	6 in.
No. 22.—An interval (not well seen) of beds of greenish blue shale and argillaceous limestone, each varying from eight to twelve inches, showing abundant fossils of the *Trenton*	16 ft.	
No. 23.—Blue, earthy limestone (under water) seen		6 in.
Total	103 ft.	10 in.

It is impossible, without more examination, to fix certainly the equivalency of any portion of this section with those at Mantorville, but Nos. 2 to 4 here are probably included in No. 6 at Wilson's quarry. This section shows the transition from the *Trenton* to the *Galena* to have been gradual in southern Minnesota, the occurrence of the buff and magnesian layers marking those changes favorable for the deposition of *Galena limestone* which preceded the full introduction of that epoch.

The foregoing sections of the *Trenton limestone* with its associated shales are thought to cover the whole formation, which probably reaches the thickness of 160 feet in the southern portion of the state, where, only, its full development is preserved.

(d.) *Fossils of the Trenton limestone.*

It is not intended to attempt here, nor would it be possible at the present time, to give a complete list of the numerous and interesting fossils supplied by the *Trenton limestone.* Full collections have not yet been made, but enough has been done to illustrate the commonest of the animal remains met with in this formation, and to show how essential to the geologist a knowledge of the fossils of any rock is, before he can pronounce on its age. Perhaps the most common fossil seen about outcrops of the *Trenton* in Minnesota is a ramose form of the little coral *Chætetes*, probably of the species *Lycoperdon.* It seems to pertain specially to the beds of shale, but is not absent from the other beds. On the weathering away of the rock, the fragments fall out, and may be picked up along the foot of many of the outcrops of this limestone. Besides this coral, *Leptæna deltoidea*, a small brachiopod, is frequently seen. There are also different species of *Orthis*, of *Strophomena* and of *Tellinomya*, and a species of *Leperditia.* Of gasteropods, species of *Murchisonia* and *Pleurotomaria* are the most common. Trilobites of the genera *Isotelus*, *Illænus*, *Phacops* and *Lichas*, and also doubtfully of *Calymene*, have been found within the state. Of cephalopods there are a great many species, as well as a great number of individuals. In some cases the rock seems entirely made up of the remains of cephalopods. Some are very large, measuring nearly a foot in diameter, and some are very small. *Endoceras magniventrum* is perhaps the most common cephalopod, being at the same time one of the largest.

(e.) *Uses of the Trenton limestone.*

The frequency of the shale beds, and sometimes the intimate dissemination of shale through the calcareous layers without showing regular lamination, render the most of this formation of little use for a building material. The flags, however, near the base of the formation (For. 3. a, of B. F. Shumard)* serve in many places as a very useful stone for building purposes. The color is gray or bluish, with mottlings of lighter color. These beds are extensively wrought at St. Paul and Minneapolis, as well as at nearly all available points in the state where a local demand exists. The quarries at Minneapolis in these beds are owned by Michael Mullen, John

*In Dr. Owen's final report the engraved sections of B. F. Shumard embrace F. 3. a, b. and c., all in the rock seen at St. Anthony; but Dr. O. in his table of genera and their distribution places F. 3. b., in the "lead bearing beds of the Upper Magnesian", and F. 3. c., in the "coralline and Pentamerus beds" of the same.

Reulstertz, Henry Wacks and Mr. Evison. They are situated on the west side of the river, in the bluffs, about a quarter of a mile below the falls of St. Anthony. Other quarries are opened on Nicollet island.

It is observable that further to the south, as at Faribault, Rochester and St. Charles, these beds, although on the same horizon as those so extensively used at St. Paul and Minneapolis, are much freer from argillaceous matter, while at the same time the thickness of the distinct shale beds (as No. 2 in the section at St. Charles, and No. 1 of the section at Rochester, on Mr. O. P. Whitcomb's land) becomes much greater. There seems to have been a more disturbed condition of the oceanic waters in the central than in the southern portion of the state during the deposition of this flagging (F. 3. a, Shumard), mingling the coarser, more foreign materials of the shale intimately with the calcareous accumulations and to that extent lessening the supply for the shaly beds proper. By reference to the foregoing sections it will be seen that at the falls of Minnehaha the alternations of these lithological and chemical characters in the lower *Trenton* occur about as represented in the following view, No. 4. being that from which the building stone is taken.

1	Shale, (not seen.)
2	Calcareous...................................... 9 feet.
3	Shale... 4 feet.
4	Shaly limestone...............................13 feet.
5	Shale... 4 feet.
6	St. Peter sandstone.

At Rochester the same horizon shows the following alternations, number four being the principal quarry-stone.

1	Shale...14 feet.
2	Calcareous, (wanting.)
3	Shaly... 2 feet.
4	Pure limestone...............................17 feet.
5	Shale...10 feet.
6	St. Peter sandstone.

In the former case we find about eight feet of shale and thirteen feet of shaly limestone, with nine feet of a vesicular (magnesian?)

limestone. In the latter case we find about twenty-five feet of shale in considerable and distinct beds, and seventeen feet of pure limestone, the upper calcareous (and magnesian?) member being apparently wanting.

The quicklime made from the *Trenton limestone*, is easily slacked and with a rapid evolution of heat. It also sets with greater rapidity than that made from the *Lower Magnesian*. It requires an intenser heat to drive off the carbonic acid from the lime of the *Trenton* than it does from the lime and magnesia of the *Lower Magnesian*. Hence more fuel is consumed. In the use of the lime, however, a smaller insoluble sediment will result from the slacking of that made from the *Trenton*, when free from shale, than from that made from the *Lower Magnesian* when equally pure.

At Faribault, in Rice county, the principal quarries that furnish stone (and also marble) are those of Milan N. Pond and Mr. Cromer, situated one and a half miles east of the city, in bluffs at some distance from the river. Quarries are also owned near the city, in the river bluffs, by Wm. Lee and Mr. Donahue and by others. The stone here is all from the same stratigraphical horizon as the quarries at Minneapolis, but is much less shaly, some layers being 18 to 20 inches thick after being dressed. The stone used in the asylum for the deaf and dumb, at Faribault, was taken from Pond and Cromer's quarries. But in the construction of this handsome edifice the common mistake is made of placing some of the stone on edge. This is the case all round the building near the basement. The first stone below the water-table has a thickness of six or eight inches, and a width of three feet, and stands on edge. This is backed up probably with smaller, poor stone in irregular courses without cross-bindings. The faced stone is placed hence in its weakest position in the wall, and in one in which it is most susceptible to the attacks of the weather, and the wall itself is weakened by being split into two separate walls. This is a common oversight on the part of stone masons, some of the largest and costliest buildings in St. Paul and Minneapolis, including the university at St. Anthony, exhibiting the same short-sighted economy in their architecture. It should be an invariable rule never to lay a stone in an important wall so that the layers of sedimentation are perpendicular instead of horizontal. The more nearly a stone can lie in a wall as it lay in the natural rock, the firmer is the wall.

The Episcopal church and chapel and the school building belonging to the same society at Faribault, as well as the public school houses of the city, and some large business blocks are laid up with this limestone.

The "Faribault marble" is a bed in the same quarries, lying between common building-stone layers, and having a thickness of something less than a foot. It is susceptible of a fine polish, and has a gray color. It is made into table and stand trimmings which show various markings and mottlings, owing to the contained fossils and the various lithology of the stone.

6. THE GALENA LIMESTONE.

(a.) *Its area.*

The line of junction of the *Galena* with the *Trenton* is pretty well marked in the southeastern portion of the state through the counties of Fillmore and Olmsted, but its junction with the *Maquoketa shales* has not yet been observed at a single place. Hence the width of the *Galena* belt is unknown, although it does not probably exceed ten miles. In the southwestern portion of Goodhue county the *Galena* is deflected toward the west, and finally in Rice and Waseca counties toward the southwest, passing through Faribault and leaving the state in Martin.

(b.) *Its lithological characters.*

This limestone was included by Dr. Owen in his designation "Upper Magnesian limestone," that term also covering the *Niagara limestone* which is separated from the *Galena* by a thickness, unobserved by Dr. Owen, of about 75 feet of shales named by Dr. C. A. White of Iowa the *Maquoketa shales*. It was, however, distinguished by Dr. Owen under the special designation of "lead-bearing beds of the Upper Magnesian." Lithologically it has a great similarity to the *Niagara*. Its usual color is buff, although on deep and fresh quarrying it also shows that its normal color, like most other limestones, is blue. Its composition, like that of the *Lower Magnesian*, is dolomitic, comprising a large percentage of carbonate of magnesia. Its texture is open, even porous, with minute cavities. It also exhibits large cavernous patches, with a rough and forbidding aspect. These, however, are not common, the sedimentation having been generally so undisturbed by chemical or mechanical agencies that the layers are yet well preserved. The grain is crystalline, and sometimes granular. Minute crystals of brown spar often line the cavities. It also sometimes embraces iron pyrites which, weathering out, stains the face of the rock with a rust of iron. It probably also embraces galena in some parts of its area in Minnesota, although this mineral has not actually been found contained in the rock. Pieces of considerable size are found by the farmers in Olmsted county in plowing near the bluffs of this formation, which have apparently fallen down on being loosened by the weather, the drift there being comparatively light. The lower beds of the *Galena* are interstratified with the *Trenton.* This may be seen by comparing the sections covering that horizon at Mantorville and at Pettit's mill. (See pages 99 and 100.) A thickness of about 20 feet is taken up by alternating shale and limestone, the latter gradually losing its distinctly dolomitic characters and passing into the grayish and blue compacter beds of the *Trenton.*

In the southeastern portion of the state, where the *Galena*, owing to the thinness of the drift deposit, is seen in the bluffs and terraces with which the face of the country is diversified, its irregular outline is easily traceable for many miles. It forms the summit of a distinct terrace of which the underlying *Trenton* shales and limestones constitute the foundation, and from the top of which the overlying *Maquoketa shales* seem to have been denuded. It thus shows its more persistent character more distinctly than if it lay between formations of equal hardness. Its thickness is estimated at 180 feet.

The lithological character of the *Galena* is also frequently evident in the form of precipitous escarpments, and prominent, often detached, crags along the valleys of streams, where their channels are deeply cut. The point lying between two valleys which unite is sometimes wrought by the combined action of water and air into picturesque or fantastic shapes, the beauty and grotesqueness of which is hightened by the seclusion of the place. These unevenly weathered surfaces are due to variations in the hardness and durability of the texture of the *Galena.*

Some of the observed sections in the lower portions of the *Galena* have already been given under the head of the *Trenton limestone.* Those at Mantorville and Pettit's mill expose upward of 40 feet of this formation, and need not be repeated here. The beds exposed in Mr. Thomas Garrick's quarry, on sec. 18, in Rochester, Olmsted county, show about 25 feet of a very uniform and evenly bedded stone, of a buff or light cream-color, and crystalline, often granular texture, in which are many cavities from which the fossils have been absorbed, besides often a minutely vesicular and open structure.

(c.) *Fossils of the Galena limestone.*

Wherever the *Galena* has been examined in Minnesota, the most striking, and perhaps the commonest fossil is the sunflower coral, *Receptaculites.* Examination sufficiently detailed has not yet been made to establish the species to which specimens collected may belong. There can be but little doubt, however, that the usual species at Dubuque (*Oweni*, Hall) is also the most common in southern Minnesota. *Orthoceratites,* sometimes of large dimensions, are also common in the *Galena*, especially near the base. Species of *Murchisonia*, and apparently of *Pleurotomaria* have also been seen. Of brachiopods various species that appear like *Orthis* and like *Strophomena*, in addition to *Lingula quadrata* (Eichwald,) have been collected from the outcrops of the *Galena.* The paleontology of the *Galena* is studied under unfavorable circumstances arising from the crystalline condition of the rock, which has generally caused the absorption of the shelly portion of the animal, leaving only its shape entombed in the form of a cast. In other cases the fossils are so nearly obliterated by this means that the casts themselves are chemically united with the mass of the rock, rendering their separation impossible.

(d.) *Economical value of the Galena limestone.*

This limestone derives not only its name but its special interest to the geologist and great economical value to the states further south, from the occurrence in it of workable and valuable deposits of the sulphurets of lead and zinc, called galena and blende. These deposits specially prevail in that district denominated by Prof. J. D. Whitney "the driftless region," in the states of Iowa, Wisconsin and Illinois. This driftless tract spreads much further northwestward, covering much of the southeastern portion of Minnesota. Fully admitting Prof. Whitney's theory as to the non-submergence of this region since the deposition of the Silurian limestone, there are many facts which will not permit such non-submergence to explain the apparent absence of the northern drift in that part of the Northwest, chief among which is the absence of proof that any portion of the drift of the Northwest is due to general submergence below the waters of the ocean. The fact of the thinness of the drift in southeastern Minnesota has been referred to under the head of *surface geology*. The features of surface that prevail throughout this district are the same as those seen about Dubuque, in Iowa, and generally throughout the "lead region of the upper Mississippi." The characters of the *Galena limestone* in Minnesota are essentially those of the same limestone in the lead district. The evidence is therefore presumptive of the existence of galena in workable quantities in the northern extension of this formation in Minnesota; at least no cause is known for the limitation of the lead-bearing area to the district in which it is chiefly developed. If the origin of the sulphurets that fill the cavities in the *Galena* be due to the infiltration of those minerals from oceanic waters holding the sulphates of the same metals in solution at the time of the formation of that dolomite, there is no known reason why the *Galena* will not embrace the same sulphurets throughout its extent, at least wherever the causes that produced the precipitation were in force. The cause of that chemical change, assigned by Mr. Whitney, is the decomposition of vegetable and animal remains in the underlying "bituminous" shales of the *Trenton*, a process which, evolving sulphur in the form of sulphuretted hydrogen, would necessarily convert the sulphates in the waters through which it rose, into the corresponding sulphurets. The precipitates gathered in such shrinkage cracks or other cavities as were favorable for its accumulation. These conditions all prevailed, so far as can be learned from the appearance of the rocks themselves, in southern Minnesota equally with southern Wisconsin. When in connection with these theoretical considerations it be remembered that occasional cuboidal pieces of galena are found in the soil in that part of the state where this dolomite occupies the surface, it may be regarded as quite probable that the lead-bearing area extends also into the state of Minnesota, and that by careful and systematic exploration it may be found in the rock itself in paying quantities.

For lime the *Galena* is not much used in Minnesota. Yet it will make a lime of superior excellence. It will burn easily and cheaply owing both to its vesicular texture and the presence of magnesia in the form of a carbonate. It will make a lime of considerable body, but less quickness in slacking and setting than that from the *Trenton.* In that respect it would resemble the quicklime from the *Lower Magnesian*, but it would be whiter, and freer from siliceous matter. The granular texture seen in some parts of the *Galena*, a character common to most magnesian limestones, has sometimes made it pass for a sandstone, and for that reason, although used for a building material, it has not generally been tested for quicklime. Lime for the local markets of southern Minnesota ought all to be supplied from this formation. It furnishes in many of its exposures, along the valleys of streams, the best of opportunities for quarrying.

When in connection with its fitness for quicklime, its merits as a building stone are considered, it is made a little surprising that no more working in this formation has been done. It not only furnishes a building material suitable for all ordinary uses in foundations and abutments for bridges, but it also cuts easily to a regular and smooth surface. Its bedding is sometimes heavy, reaching two or three feet in thickness, and the stone is strong enough to endure both pressure and long weathering. It is of a light and lively color, and in that respect has the advantage of darker colored stone. The quarries at Mantorville, owned by Messrs. Wilson and Ginsberg, have furnished a large amount of good building stone which has been hauled many miles over the country in various directions, past many inviting outcrops of the same formation. It is owing to the investigations of an amateur geologist,* that the existence of this stone in many other places has been made known to the citizens of Olmsted county. Through his recommendations it has recently been opened near the city of Rochester, and is found to supply a stone equal in all respects to that taken out at Mantorville. The quarry of Mr. Thomas Garrick, on section eighteen in the township of Rochester, Olmsted county, exposes twenty or twenty-five feet of evenly bedded *Galena*, useful for general building. At Rochester, Cook's block, the court house, the public school-house and Heaney's block are all faced and trimmed with the *Galena*, hauled from Mantorville. At Mantorville the court house and the school-house are entirely built of it; the former, however, showing several large iron stains in the front walls.

*Mr. W. D. Hurlbut, of Rochester, Minn.

7. UPPER SILURIAN AND DEVONIAN.

The formations that have thus far been described are all included below the Upper Silurian. The *Maquoketa shales* of Iowa, which overlie the *Galena* are also embraced in the Lower Silurian. The *Galena*, however is the highest member of the Silurian that has yet been identified in the state. It is expected that when more detailed exploration shall have been made, the remainder of the Lower Silurian, the upper Silurian and the lower portions of the Devonian will be found to occupy a considerable area in the southern portion of the state. The areas assigned to these rocks in the preliminary map accompanying this report are hence based on the known trend of other formations, and on the maps of the neighboring state of Iowa, which show the Upper Silurian and Devonian as leaving that state and entering this. The same is true of the areas given these rocks in the northwestern portion of the state, the geological map by Prof. H. Y. Hind, of the Winnipeg district, representing the Devonian and Upper Silurian as entering Minnesota from the north.

8. THE CRETACEOUS.

(a.) *Preliminary considerations.*

The geological frame-work of the state having been completed by the deposition of the foregoing Silurian (and Devonian?) rocks, it remained above the oceanic waters during the whole of the Carboniferous and a greater part of the Mesozoic ages, during which it underwent only the vicissitudes of atmospheric changes, till the period of the *Cretaceous*. Large portions of the American continent which are now dry land were yet under the waters of the ocean. At the ushering in of the *Cretaceous* a further submergence brought the *Cretaceous* seas over not only the old Devonian and Silurian dry land, but also in the states of Minnesota and Iowa* over large areas of the azoic and granitic rocks. How much of the state of Minnesota was thus submerged has not yet been ascertained.

If points of elevation only be considered, since it is found in some of the most elevated parts of the southern portion of the state, the entire state must have been submerged. It is possible the surface of the country sank below the ocean unequally, in different

*Compare *Geology of Iowa*, 1870, Vol. I, p. 168.

localities, and also that it rose with similar irregularity. Hence points that now show the greatest altitude above the ocean level, may have been the deepest submerged, or may have risen last. Those points also, in the state which show less altitude above the the ocean may have risen first, or may not have been submerged at all. Whatever may be the facts in regard to the northern portion of the state, which is considerably less elevated above the ocean than the southern, the seas of the *Cretaceous* certainly covered the most of the southern half of Minnesota, and probably a wide belt along its western border, reaching to the national boundary line on the north. Thus the rough frame-work of the older rocks was furnished with an outer integument which tones down their angularities by filling some of their depressions, the *Cretaceous* beds lying unconformably on them all. No attempt will be made at this stage of the survey to define the limits of the Cretaceous in Minnesota. It is said to occur in the southwestern part of the state, on the Cottonwood river, where it contains beds of lignite that have been mistaken for the outcroppings of the northern rim of the Carboniferous. It has been detected at Austin, in Mower county, where it affords angiospermous leaves. It has been described in Stearns county by Mr. Kloos. It probably occurs at Spring Valley in Fillmore county. At Stillwater is a bed of *tripoli* which is believed to belong to the *Cretaceous*. It is exposed in a little tributary of the St. Croix river about one mile north of the city. Dr. C. A. White has lately announced it at Lime Springs, in Howard county, Iowa, about five miles south of the Minnesota state line. Howard county, in Iowa, is south of Mower and Fillmore counties in Minnesota. Thus the question of the eastern limit of the *Cretaceous* in the Northwest is still an open question. The writer is not aware of any announcement of its existence in the state of Wisconsin. But on the eastern shore of lake Michigan, in the "Grand Traverse region" of the state of Michigan, occur beds of lignite associated with soft, bituminous and green clays that have been regarded as pertaining to the drift.* Mr. A. D. White, of the Michigan survey, since deceased, maintained in 1860, in his unpublished field-notes, that these lignites and clays are not of Quaternary age. Lignites of the same or similar origin also occur on the shores of lake Superior, and have in like manner been ascribed to the age of the drift. It becomes a question of great

*See *First biennial report of progress on the geological survey of Michigan*, 1861, p. 130.

geological interest to determine the age of these lignites, especially as lignites supposed to occupy a position near the bottom of the drift, also are reported in southern Illinois and Ohio. Besides the lignites connected with the *Lower Cretaceous*, Dr. F. V. Hayden describes many beds of lignite in the *Lower Tertiary*. What portion, if any, of the lignite beds seen in different parts of Minnesota may be of *Tertiary* age, it is not now within the province of the survey to state. The *Tertiary* may also be represented.

The rocks of this age being so little known and so meagerly represented in Minnesota, the following classification will be of value for the information of the citizens of the state and for convenience of reference in the future progress of the survey. It is essentially that of Messrs. Meek and Hayden, and is based on their examinations on the upper Missouri. It is arranged in descending order.

LATER CRETACEOUS.

No. 5. *Fox Hills group*. Yellowish and ferruginous sandstones and arenaceous clays. Characteristic fossils—*Nautilus Dekayi*, *Ammonites placenta*, *Ammonites lobatus*, *Scaphites Conradi*, *Baculites ovatus*, *Mosasaurus Missouriensis*. Thickness.................500 feet.

No. 4. *Fort Pierre group*. Dark clays; plastic or laminated; sometimes calcareous. Characteristic fossils—*Nautilus Dekayi*, *Ammonites placenta*, *Ammonites complexus*, *Baculites ovatus*, *Baculites compressus*, *Helicoceras Mortoni*, *Inoceramus sublevis*, *Mosasaurus Missouriensis*. Thickness.................................700 feet.

EARLIER CRETACEOUS.

No. 3. *Niobrara group*. Grayish, calcareous marl, sometimes in massive layers of chalky limestone suitable for building. Characteristic fossils—*Ostrea congesta*, *Inoceramus problematicus*, *Inoceramus aviculoides*, *Inoceramus pseudo-mytiloides*. Thickness...........200 feet.

No. 2. *Fort Benton group*. Black, plastic or laminated clays, with some thin layers of limestone and sandstone. Characteristic fossils—*Inoceramus problematicus*, *Inoceramus umbonatus*, *Ostrea congesta*, *Pholadomya papyracea*, *Ammonites percarinatus*, *Ammonites vespertinus*, *Scaphites larvæformis*. Thickness.............800 feet.

No. 1. *Dakota group*. Yellowish, reddish and whitish sandstones, with some arenaceous clays and even pudding-stones, embracing lignite and impure coal, with many impressions of angiospermous leaves, and sometimes large quantities of petrified wood. Characteristic fossils—*Pharella Dakotensis*, *Axinæa Siouxensis*, *Cyprina arenaria*, *leaves of angiosperms*. Thickness...................400 feet.

(b.) *Lithological characters of the Cretaceous.**

The stone exposed at Austin, in Mower county, is, in its natural color, light blue, and that color shows on most of the quarried

*The rock here described is of the Devonian. The fossil leaves mentioned were from Cretaceous shale lying in cavities in the rock.—N .H. W.

blocks about the heart of the bedding; and on deep quarrying it is doubtless all blue. Yet the stone seen about the village is very generally of a buff color, to the depth of half an inch to three inches, depending on the amount of weathering and oxidation. The thinner beds are altogether changed to that color. The presence of considerable concretionary iron and mud balls causes a rusty stain of a yellow color over the surface of many of the slabs. These concretionary balls fall out or dissolve out when in the water, and leave cavities which become larger still. Besides these, which are not common in the compact portion of the stone, but are oftenest seen among its thin beds, there are also cavities disclosed by the fracture of the homogeneous thick beds. These are sometimes perfectly empty, but often contain loose friable matter, easily picked out but not different in color or grain from the mass of the rock. At other times such cavities, revealed on the fracture of the stone, are lined with a perfect coating of fine mammillated crystals which are naturally white and as hard as quartz, but often covered with iron-rust so as to present a red or black exterior. They are much like drusy quartz. The texture of the stone itself is usually close, and the grain is homogeneous. Some large slabs and blocks are sawn for bases to tombstones, and worked down to a very smooth surface. It is more safely sawn to any desired dimensions than cut or broken, since it fractures treacherously. Yet it is not in the least crystalline. Its aspect at a distance is that of a fine-grained sandstone. Yet it contains no apparent grit. It is so soft that it can be cut without difficulty, appearing much like an unusually indurated blue shale. It contains, but very sparingly, a few molluscous fossils which appear like a *Gryphæa*. It evidently weathers away fast, since the rotted down beds have to be removed at the quarry to the depth of nearly four feet before any stone is met worth taking out.

Just back of the place where this stone is slightly worked at Austin, perhaps fifty rods distant and 14 feet higher, in the excavation of one of the low knolls which superficially appeared to be only sand, like others opened for that purpose nearer the river, a German struck stone of the same kind within two or three feet of the surface. It consists of thin, shattered beds, all of a buff color. Enough, however, was obtained, of suitable quality, for the vault and other masonry appertaining to a small brewery. Indeed the greater portion of the cellar is dug in it. It was overlain by the following section of clays, which may not be of *Cretaceous age*.

No. 1.	Black sandy loam and soil	2 to 4 feet.
No. 2.	Band of red and variegated compact clay	6 in. to 4 feet.
No. 3.	Yellow ocherous band of clay	6 in. to 4 feet.

These bands of clay (Nos. 2 and 3) are not so regularly superimposed as indicated by the above section, but occasionally No. 3 is broken through or is wanting, and No. 2 lies on the rock, or passes down into its crevices. Yet No. 3 is generally the first over the rock. They vary in thickness and swell out in shapeless masses of hard clay. Such hard masses are seen sometimes to embrace bits of angular, earthy rock, much like ocher, varying in color from a dark burnt-umber color to a lighter shade, even to buff, and appearing, when of a lighter color, much like the mass of No. 3. They can be scratched easily with a knife, and however black they may be they give a red hæmatite streak. Yet when they are faded the streak also fades into a brown or yellowish-brown, like limonite. Intermingled very irregularly with No. 2, and sometimes also with No. 3, are masses of greenish clay which has in every other respect the same outward characters as No. 2. On searching for indications of the post-Tertiary age of this deposit, none could be found. No northern pebbles or boulders could be found in it; no sand or gravel, no vegetable or animal remains. Yet in place of the northern drift materials are these hard bits of ocher (?) of angular shape and often showing conchoidal surfaces. There are also large crystalline, detached masses of apparently a siliceous limestone which is very hard and close-grained. In some cases, however, this varies to a porous and white limestone that appears to be very pure. In connection with this description of limestone masses, it is interesting to note the occurrence at St. Charles, in Winona county, of hard, siliceous limestone masses on the surface of the ground, that appear very much like those embraced in this clay. At St. Charles there is also a large mass of argentine, or lamellar calcite, lying on the surface of a slope of a hill. It was originally four or five feet across, and about a foot thick, but has been broken up for hand specimens. It appears very much like fibrous gypsum. Its arrangement in wavy and curly layers gives it much the appearance of woody fiber, and it was regarded as a specimen of petrified wood for a number of years after its discovery. It may have been originally embraced in *Cretaceous* or *Tertiary* clays which have been destroyed and transported, or it may have weathered out from the *Trenton* shales which appear in the top of the hill.

At Austin, in the digging of Mr. L. G. Basford's well, angiospermous leaves were found in the sandstone above described. The materials passed through in this well were said to be in general, as follows:

No. 1.	Soil and loam	3 to 4 feet.
No. 2.	Clay	20 feet.
No. 3.	Rock	6 to 8 reet.

About two feet of loose stone was thrown out by picking. In these pieces the vegetable fossils were found. Two distinct varieties of leaf are disclosed. One is very much like *Ficus primordialis;* the other is unlike anything with which it has been possible yet to compare it. The specimen preserved consists of a branch apparently of a small herb. An inch and three-fourths of the main stalk is preserved. In that distance it gives off four branches, each of which seems to be as large as the main stalk, three on the left and one on the right. The whole specimen is thickly furnished with decurrent, parallel-veined leaves which have a distinct midrib. These leaves are simple, entire, oblanceolate-linear, and taper-pointed at their junction with the stalk. Their length is a quarter of an inch, varying a little above and below that size; and their width is one-twentieth of an inch. The diameter of the stalk, and that of the branches, is about half the width of the leaves. The latter diverge from the branches at an angle 40° to 45°. A photographic copy of this fossil was submitted to Dr. J. S. Newberry, who pronounces it probably a species of *Sequoia*, a gymnosperm of the Pine family known as "Redwood,"

At J. Gregson's mill, two miles down the Cedar from Austin, the same rock as at Austin is observed forming a ripple so as to induce the construction of a water-power for flouring purposes. The stream here works down over about fourteen feet of rock. The beds are sometimes two feet or more thick, or the rock is entirely massive like an indurated shale. Yet in weathering the thick beds are checked by planes running mainly horizontal, instead of perpendicular or diagonal as in most shale. Although mainly horizontal, these planes are apt to unite after a few feet, splitting the heaviest beds out lenticularly. On considerable exposure the weather entirely disintegrates and destroys it. It is here worked a little below the dam, and some heavy and fine-looking slabs are taken out near the water's edge. Some parts are here plainly somewhat calcareous, and afford traces of fossil remains which have much the appearance of brachiopoda. These portions are porous as by absorbed fossils.

At Messrs. Rosenberry and Miner's quarry, near Mr. Gregson's mill, the exposed section is as follows, in descending order:

Section near Austin, in Mower county.

No. 1.—Black, loamy soil	7 to 8 ft.
No. 2.—Loose fragments of the underlying beds, and clay, mixed	3 ft.
No. 3.—Heavy stone like that described at Austin, clay filling planes and joints	10 to 12 ft.
No. 4.—Rusty bituminous films	½ to 1 in.
[On the authority of the owners of the quarry, to this section may be added, below the foregoing, the following:]	
No. 5.—Limestone, filled with shells, blue, contains flint, makes lime, penetrated	2 ft.

The bedding of No. 3 sometimes lies in detached blocks before being quarried, the corners and angles of which are replaced by clay, and the color of the stone is changed from blue to buff or drab to the depth of about two inches.

Along the sides of this quarry is considerable blue clay, containing no shells or fossils of any kind. It is exceedingly fine and plastic. It fills the openings in the rock, and is said to run down thirty feet at least, where the stone itself would naturally lie unless the beds have been considerably broken and removed. It seems to occupy a trough-like excavation in the rock about a rod wide, and has been traced by means of an iron rod several yards back from the river bank. This clay below twenty feet becomes white. This trough extends east and west.

One mile below Gregson's mill, at the mouth of Rose creek, about the same thickness of the same kind of stone may be seen in the bank and bed of the creek.

It is exposed again at Officer's mill, one mile below Rose creek, where the river passes, in the form of a little ripple, over the rock, inviting here also the improvement of the water-power.

Two miles east of Officer's mill, a farmer has struck the same rock in two separate wells on his farm, in one at the depth of three feet, and in the other at eleven feet.

Below this place no rock is said to occur in the river, differing from this, till at or near Mitchell or Osago, in the state of Iowa, twenty-eight miles from Austin, where quicklime is made from rock taken from the bank of the river.

Mr. Thomas Smith, on S. E. ¼ sec. 12, T. 102, R. 17, a few miles east of Austin, has discovered coal in the sinking of one or two wells on his farm. It has not yet been possible to compare this locality with that on the Cottonwood river, where coal is said also to occur in limited quantities; but they are both believed to be beds of lignite appertaining to the *Lower Cretaceous*. These localities will both be visited early on the opening of another season of field-work.

At Spring Valley, in the western part of Fillmore county, is an extensive bed of variegated and white clay that is generally very fine, but also sometimes embraces coarse sand grains.

Near Mankato, in Blue Earth county, the banks of the Minnesota river disclose sections of variegated and white clay.

It is not intended here to convey the fixed belief that these clays are of *Cretaceous* age. They occur in other places in the southern part of the state, and time has not yet been afforded for giving them the requisite examination. These remarks are appended to the foregoing description of rocks supposed to be of the age of the *Cretaceous*, because these clays have been seen frequently associated with those rocks, and because they do not appear to be of *Quaternary* age. When chemical examinations of these clays have been made, more positive information concerning their age and value will be received. Samples from different parts of the state have been duly collected, and submitted to the chemist of the survey.

(c.) *Economical value of Cretaceous.*

The sediments of the *Lower Cretaceous* being mainly siliceous are made up of sandstones and arenaceous clays. These clays may be distinctly arenaceous, or the sediments may be so fine that the individual grains are not distinguishable by the unaided eye. The sandstones at Austin are very fine-grained. They are utilized by Messrs. Rosenberry and Miner in the construction of bases for monuments. These blocks are sawn out by the proper machinery and given a high polish by the usual methods. The closeness and fineness of the grain render the stone capable of taking a very smooth surface. By first marking with a steel point, and properly guiding the fracture, it is cut into pieces of any dimension. Its perfect homogeneity of texture enables the cutter to depend on its checks. It makes very fine hones for razors and cutlery. It is also used instead of the celebrated "Scotch hone" for polishing marble. It is being introduced for that use into the chief markets of the Northwest from the quarry of Rosenberry and Miner. It is furnished by them to wholesale dealers in Chicago at $25 per ton. It is retailed at forty cents per pound, the Scotch hone selling for fifty cents per pound.

The bed of *tripoli* located at Stillwater, in Washington county, seems to consist almost entirely of silica, like this sandstone. Yet, its outward resemblance to many clays that are met with in the drift makes it uncertain to what age it belongs. It lies below a great mass of drift materials closely sheltered in a nook between the bluffs of Brown's creek, and if it be of *Cretaceous* age, its position alone has preserved it from the destroying action of glaciers. It is of a reddish or copper-color, the same as that of the drift clays adjacent. Its exposed thickness is about twenty feet, and it is in some places interstratified with distinct quartz sand. Yet the tripoli clay makes up the mass of the bank, the sand layers being nothing more than partings. About fourteen years ago a company was formed for the purpose of developing this deposit as a material for polishing, but nothing of importance was done. Mr. Abraham Van Vorhes, of Stillwater, is authority for the statement that about that time samples were analyzed by Professor Joseph Henry, of Washington, and by Dr. Jackson of Boston. They agreed in pronouncing it a very fine article of tripoli, equal to the Bohemian. It is at present only used to a limited extent by machinists for polishing brass and iron, and by cabinet makers for polishing varnished wood-work. A thin paste is made and the material applied usually with cork.

The clay at Rosenberry and Miner's quarry, near Austin, in Mower county, is used for putty, by simply mixing it with boiled linseed oil. It is first dried and thoroughly pulverized. It is said to act as firmly as Spanish whiting. The orcherous clays may in some places be made useful in the manufacture of a fine mineral paint.

At New Ulm, in Brown county, are two flourishing potter's establishments, owned by Messrs Dauffenbach and Gieseke, and by John Stekœrt. At the former a blue clay "from the Cottonwood" is mixed with a similar blue clay obtained from the drift at New Ulm. The latter overlies a heavy stratum of waterwashed and stratified white sand. It is said to be necessary to mix these clays to obtain a material that will not crack in the kiln, that "from the Cottonwood" being much addicted to that fault. The same clay makes a red brick when harder burned. A white clay is also used by Dauffenbach and Gieseke for making fire-brick. Their kiln and fire-arch are built of brick of their own manufacture from this clay, and appear to stand well. This clay is obtained at some distance from New Ulm, at a point said to be known only to the proprietors.

VI.

PLANS AND RECOMMENDATIONS.

The law under which the present survey is being prosecuted appropriates the sum of one thousand dollars per annum. This is too small, for various reasons, the chief of which are:

1st. It will not pay for the services of a single employe on the survey capable of working under the law. Hence, it well-nigh renders the law inoperative.

2nd. It does not command the respect and confidence of the citizens of the state and others, and serves as an excuse for refusing aid and co-operation. The survey should be independent of favors for which it now has to beg, sometimes to be scornfully rebuffed.

3d. In the survey of those portions of the state inaccessible by public roads, or by railroads, it will be necessary to employ laborers, and incur other expense, for which the sum of one thousand dollars is not sufficient.

4th. In order to conduct the survey on one thousand dollars per annum, the state geologist must find some other employment a portion of the year.

5th. The magnitude of the interests involved demands that ample means be allowed for doing the work of the survey thoroughly and without embarrassment.

These considerations ought to induce the Legislature to increase the amount now appropriated to a sum sufficient at least to keep one man constantly employed, and to pay all expense of field-work and chemical examinations.

In connection with the subject of increasing the means provided for the geological survey, it is suggested that the state lands known as *salt lands* may be so sold or appropriated, under the management of the board of regents of the university, as to be available for that purpose. It would be in perfect consonance with the original design in the reservation of these lands from sale, if they were placed in the custody of the board of regents, conditioned on their use in the prosecution of the geological and natural history survey of the state, with a view to the early and economical development of the brines of the state.

The law cannot be carried out without the purchase of chemicals and apparatus for the use of the chemical department of the survey, and without the purchase of instruments to be used in the prosecution of the field-work. It is too much to ask the state university, which now pays the services of the chemist of the survey besides furnishing rooms for laboratory work, to provide for these expenses. There ought to be a special appropriation of several hundred dollars to make these purchases. The board of regents are referred to the accompanying statement of Prof. D. P. Strange, chemist of the survey, for information on this subject.

The law creating the survey is very explicit in defining the work to be done. It requires that the geological survey proper, unless otherwise ordered by the board of regents, shall be first completed. Hence no steps have been taken toward the performance of anything not strictly *geological.* Indeed it is beyond the means afforded at present to do any work in the botanical and zoological departments, before the substantial completion of the geological portion of the survey. It is evident, however, that the aggregate expense of the geological and natural history survey will be considerably reduced by carrying on the different departments in conjunction. It would be duplicating at considerable expense, the various parties and explorations, to delay all observations and collections illustrative of the zoology and botany of the state till after the geological observations had been made. Parties would have to be sent again over much of the same territory. A special botanist or zoologist might accompany the geological party without much additional expense, making valuable collections that might otherwise be lost. Thus in an economical sense, as well as in a grander and deeper sense depending on their co-adaptation, these sciences cannot be divorced. They cannot act independently of each other. In the prosecution of the geological survey many opportunities will be offered for the furtherance of the botanical and zoological investigations.

Prof. E. H. Twining, late of the university of Minnesota, now of the university of Missouri, has furnished the accompanying list of plants found by him growing on the university grounds during his residence here as professor of chemistry in the state university.

In the prosecution of the geological survey proper, after a general reconnoissance with a view to the determination of the general trend of the formations, and the identification of sufficient characters to decide their ages, it will be necessary to enter on the detailed examination of the state by counties. This more special investigation implies the careful delineation of the outlines of the formations with all their windings, as they are found in each county, together with a scientific account of the chemical and mineralogical characters of the rocks found therein. In the progress of the survey the specific names of the fossils pertaining to the various formations will be ascertained, and in the end complete lists of these ancient faunas will be made out, to which will be added descriptions and figures to illustrate any new species that may be discovered. These investigations necessarily require much time and study, to say nothing of the labor of collecting and preserving the specimens.

The question of the existence of brine in the state of Minnesota is one of the most important, in an economical sense, that can be presented for the investigation of the survey. It should not be hastily answered. Too much is involved to be rested on the result of a guess. Too much also is involved to be prejudiced by the failure of unguided expenditures. The tests that may be made ought to be made in the fullest light of all the facts that science with its generalizations can throw upon them. It comes within the scope of geological investigation, and ought not to be hazarded in the hands of empirical novices.

The salt springs said to occur in this state may have either of two origins. They may be the results of overflow of extensive salt basins embraced in the rocky structure of the state, or they may be the result of superficial accumulations similar to the other saline and alkaline deposits that are scattered largely over the western plains. It is not intended now to give this question the discussion its importance demands at the hands of the survey. No investigation of the phenomena of the regions where these springs exist, has been made. It is only intended to suggest the importance of correct scientific processes in the future efforts for their development.

It is recommended that the law ordering the survey be amended so as to require the board of regents to supply suites of duplicate geological specimens collected to the state normal schools, after the university collection shall have been completed.

Very respectfully submitted,

N. H. WINCHELL,
State geologist.

UNIVERSITY OF MINNESOTA,
ST. ANTHONY, MINN., Dec. 31, 1872.

STATEMENT OF THE CHEMIST OF THE SURVEY.

Prof. N. H. Winchell, geologist of survey:

SIR:—I have to report that I have been utterly unable to do any chemical work upon the geological survey to the present, owing to the lack of necessary apparatus, and also to the impossibility, with present heating facilities in our laboratory, of conducting any chemical analysis during the winter season.

Very respectfully,

D. P. STRANGE,

Chemist of survey.

LIST OF PLANTS.

Mostly herbaceous in the neighborhood of St. Anthony, Minnesota—principally found on the university grounds.
1869—1872.

BY PROFESSOR E. H. TWINING.

RANUNCULACEÆ.

Ranunculus rhomboideus.
R. repens.
R. abortivus.
R. Pennsylvanicus.
R. sceleratus.
Anemone Nuttalliana.
A. nemorosa.
A. Pennsylvanica.
A. cylindrica.
A. Virginica.
A. thalictroides.
Actæa spicata.
Aquilegia Canadensis.
Thalictrum Cornuti.
Delphinium azureum.
Clematis Virginiana.
Caltha palustris.

PAPAVERACEÆ.

Sanguinaria Canadensis.

VIOLACEÆ.

Viola cucullata.
V. delphinifolia.
V. pubescens.
V. pedata.

CRUCIFERÆ.

Turritis stricta.
Arabis lævigata.
Capsella Bursa-pastoris.
Lepidium Virginicum.

GERANIACEÆ.

Geranium maculatum.
Impatiens fulva.

HYDROPHYLLACEÆ.

Hydrophyllum Virginicum.

OXALIDACEÆ.

Oxalis stricta.
O. violacea.

CARYOPHYLLACEÆ.

Arenaria lateriflora.
Stellaria longifolia.
Silene antirrhina.
Agrostemma Githago.

LEGUMINOSÆ.

Lupinus perennis.
L ochroleucus.
L. venosus.
Vicia Americana.
Astragalus Canadensis.
A. caryocarpus.
Psoralea argophylla.
Amorpha canescens.
A. fruticosa.
Petalostemon candidus.
P. violaceus.
P. villosus.
Amphicarpæa monoica.
Apios tuberosa.
Phaseolus diversifolius.
Desmodium acuminatum.
D. Canadense.
Cassia Chamæcrista.

POLEMONIACEÆ.

Phlox pilosa.

SAXIFRAGACEÆ.

Heuchera hispida.
Parnassia Caroliniana.

ROSACEÆ.

Geum strictum.
G. album.
G. triflorum,
Fragaria vesca.
F. Virginiana.
Rosa blanda.
Potentilla Norvegica.
P. Canadensis.

P. Anserina.
P. arguta.
Spiræa salicifolia.
Prunus Virginiana.
Agrimonia Eupatoria.
Amelanchier Canadensis.
Rubus Canadensis.

BORRAGINACEÆ.

Lithospermum canescens.
L. hirtum.
L. longiflorum.
Echinospermum Lappula.
E. Redowskii.
Cynoglossum Morrisoni.

VERBENACEÆ.

Verbena hastata.
V. bracteosa.
V. urticæfolia.
V. stricta.
Phryma Leptostachya.

LABIATÆ.

Mentha Canadensis.
Leonurus Cardiaca.
Lophanthus anisatus.
Stachys palustris,
S. " var. aspera.
Monarda fistulosa.
Lycopus Europæus.
Teucrium Canadense.
Pycnanthemum lanceolatum.
Scutellaria parvula.
S. lateriflora.
Nepeta Cataria.

GROSSULACEÆ.

Ribes floridum.
R. Cynosbati.

CAPRIFOLIACEÆ.

Sambucus pubens.
Viburnum.
Symphoricarpus occidentalis.
Lonicera.

RUBIACEÆ.

Galium boreale.
G. triflorum.

CORNACEÆ.

Cornus circinata.

ARALIACEÆ.

Aralia racemosa.

UMBELLIFERÆ.

Sanicula Marilandica.
Cicuta maculata.
Pastinaca sativa.
Thaspium.

CUCURBITACEÆ.

Echinocystis lobata.

ONAGRACEÆ.

Epilobium coloratum.
E. palustre.
Œnothera biennis.
O. serrulata.

VITACEÆ.

Vitis cordifolia.

RHAMNACEÆ.

Ceanothus Americanus.

LINACEÆ.

Linum rigidum.

MALVACEÆ.

Malva rotundifolia,

HYPERICACEÆ.

Hypericum pyramidatum.

CISTACEÆ.

Helianthemum Canadense.

CAPPARIDACEÆ.

Polanisia graveolens.

FUMARIACEÆ.

Dicentra Canadensis.

SARRACENIACEÆ.

Sarracenia purpurea.

NYMPHÆACEÆ.

Nymphæa odorata.
Nuphar advena.

COMPOSITÆ.

Taraxacum Dens-leonis.
Troximon cuspidatum.
Antennaria margaritacea.
A. Pennsylvanica.
Erigeron Philadelphicum.
E. bellidifolium.
Senecio aureus.
Chrysopsis villosa.
Cynthia Virginica.
Achillea Millefolium.
Rudbeckia hirta.
R. laciniata.
Heliopsis lævis, var scabra.
Coreopsis palmata.
Helianthus strumosus.
H. rigidus.
H. giganteus.
H. hirsutus.
Solidago lanceolata.
S. Missouriensis.
S. latifolia.
S. nemoralis.
S. Canadensis.
S. rigida.
Eupatorium purpureum.
E. perfoliatum.
E. ageratoides.
Sonchus asper.
Lepachys pinnata.
Aster Novæ-Angliæ.
A. cordifolius.
A. azureus.
A. lævis.
A. multiflorus.
A. sericeus.
Lactuca elongata.
Liatris scariosa.
Helenium autumnale.
Nabalus albus.
N. racemosus.
Ambrosia trifida.
Lygodesmia juncea.
Bidens chrysanthemoides.
B. bipinnata.

SCROPHULARIACEÆ.

Rhinanthus Crista-galli.
Castilleia coccinea.
Pentstemon grandiflorus.
P. pubescens.
Scrophularia nodosa.
Veronica Americana
V. Virginica.
Mimulus Jamesii.
M. ringens.
Linaria vulgaris.
Verbascum Thapsus.
Gerardia tenuifolia.
G. purpurea.

Chelone glabra.
Pedicularis lanceolata.

SOLANACEÆ.

Physalis angulata.
Solanum nigrum.

GENTIANACEÆ.

Gentiana crinita.
G. Andrewsii.

POLYGONACEÆ.

Rumex Acetosella.
R. crispus.
Polygonum Convulvulus.
P. aviculare.
P. Persicaria.

CAMPANULACEÆ.

Campanula rotundifola.
C. aparinoides.

LOBELIACEÆ.

Lobelia spicata.
L. syphilitica.

NYCTAGINACEÆ.

Oxybaphus nyctagineus.
O. angustifolius.

ERICACEÆ.

Pyrola elliptica.

PRIMULACEÆ.

Lysimachia ciliata.

ASCLEPIADACEÆ.

Asclepias ovalifolia.
A. tuberosa.
A. Cornuti.

APOCYNACEÆ.

Apocynum and rosæmifolium.

EUPHORBIACEÆ.

Euphorbia corollata.
E. maculata.
E. cyathophora.

SALICACEÆ.

Salix lucida.

ORCHIDACEÆ.

Cypripedium pubescens.
C. spectabile.
Spiranthes graminea.

ALISMACEÆ.

Sagittaria variabilis.

LILIACEÆ.

Trillium cernuum.
Uvularia grandiflora.
U. sessilifolia.
Maianthemum bifolium.
Smilacina stellata.
Polygonatum biflorum.
Allium cernuum.
Lilium Canadense.
L. superbum.

IRIDACEÆ.

Sisyrinchium Bermudiana.

AMARYLLIDACEÆ.

Hypoxys erecta

COMMELYNACEÆ.

Tradescantia Virginica.

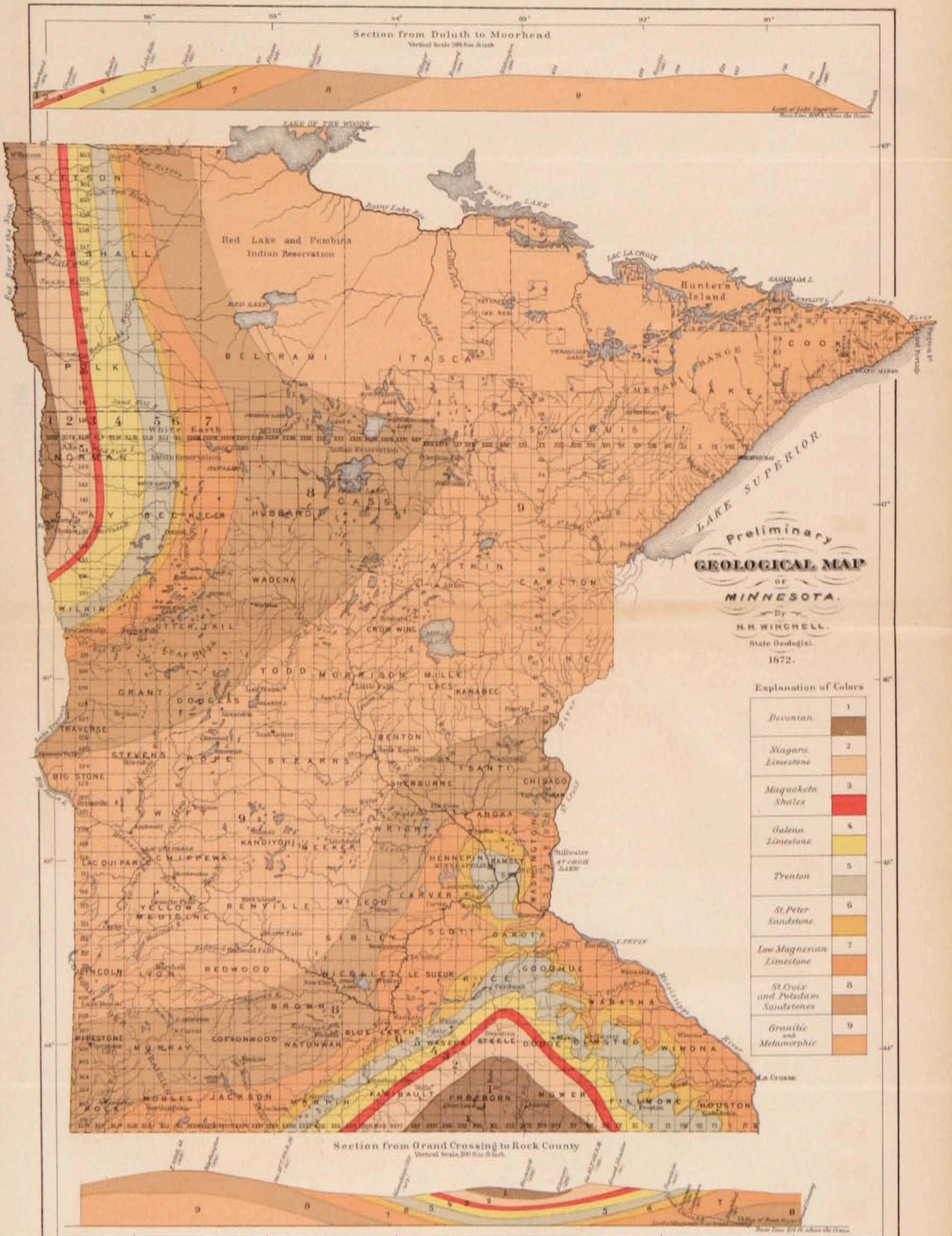
CYPERACEÆ.

Cyperus dentatus.

GRAMINEÆ.

Phleum pratense.
Setaria viridis.
Agrostis vulgaris.
Triticum caninum.
Cenchrus tribuloides.

NOTE.—The descent of the Mississippi from St. Paul to "grand crossing," opposite La Crosse, is 57 feet, as ascertained through the Milwaukee & St. Paul and Southern Minnesota railroads. If the distance between St. Paul and "grand crossing" be taken at 134½ miles, and if 22½ miles be omitted for lake Pepin, the average fall per mile of the Mississippi river is .509 feet. General Warren ascertained the average descent of the Mississippi from St. Paul to Hastings to be .556 ft. per mile.



Section from Duluth to Moorhead
Vertical Scale 100 ft to inch
Preliminary
GEOLOGICAL MAP
OF
MINNESOTA.
By
N. H. WINCHELL.
State Geologist.
1872.
Explanation of Colors
Devonian 1
Niagara Limestone 2
Maquoketa Shales 3
Galena Limestone 4
Trenton 5
St. Peter Sandstone 6
Low Magnesian Limestone 7
St. Croix and Potsdam Sandstones 8
Granitic and Metamorphic 9
LAKE OF THE WOODS
RAINY LAKE
LAKE SUPERIOR
Red Lake and Pembina Indian Reservation
White Earth Indian Reservation
Hunters Island
KITTSON
MARSHALL
POLK
NORMAN
CLAY
BECKER
WILKIN
OTTER TAIL
BELTRAMI
ITASCA
COOK
LAKE
ST. LOUIS
CARLTON
AITKIN
CASS
HUBBARD
WADENA
CROW WING
PINE
TODD
MORRISON
MILLE LACS
KANABEC
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
ISANTI
CHISAGO
BIG STONE
SHERBURNE
ANOKA
SWIFT
KANDIYOHI
MEEKER
WRIGHT
HENNEPIN
RAMSEY
WASHINGTON
LAC QUI PARLE
CHIPPEWA
RENVILLE
McLEOD
CARVER
YELLOW MEDICINE
SIBLEY
SCOTT
DAKOTA
LINCOLN
LYON
REDWOOD
NICOLLET
LE SUEUR
RICE
GOODHUE
BROWN
WABASHA
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
Stillwater
La Crosse
Section from Grand Crossing to Rock County
Vertical Scale 100 ft to inch
Julius Bien & Co. lith.