

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

N. H. WINCHELL, STATE GEOLOGIST.

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BULLETIN NO. 1.

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THE HISTORY

OF

GEOLOGICAL SURVEYS

IN MINNESOTA.

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BY N. H. WINCHELL.

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MINNESOTA GEOLOGICAL SURVEY

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# HISTORY OF GEOLOGICAL SURVEYS IN MINNESOTA.

By N. H. WINCHELL.

The first effort of the State of Minnesota to institute a survey of her domain was made in 1858 by the first Legislature that met after the admission of the state into the Union. No general law was passed, but a reprint was ordered of a portion of former reports by Prof. Daniels on the survey of Wisconsin, in which state Minnesota had then latterly been embraced.

The commissioner of statistics, Joseph A. Wheelock, also included in his official reports for the years 1859 and 1860, general summaries of the physical features and agricultural capabilities of the state, which went far toward recommending the state to eastern immigrants. The facts, however, were derived not so much from original observation as from newspaper articles, reviews and correspondence. These reports were widely distributed and introduced the state, in its diversified natural resources, favorably, to the rest of the Union, which undoubtedly was the prime object of their author.

An abortive attempt to establish a regular geological survey was made by the second State Legislature, which adopted a "concurrent resolution" ordering the appointment of commissioners to report on the geology of the state, and on a plan for a geological survey. These commissioners made separate reports, setting forth the utility of such a survey, but owing to the financial burdens which the young state had to bear, incident to the inauguration of the various public institutions, and to the opposition of governor Ramsey, the Legislature did not take any further action upon the subject.

The Legislature of 1864, however, by joint resolution, authorized the governor to appoint and direct a state geologist. The appointee was Dr. Aug. H. Hanchett, and he associated with himself Mr. Thomas Clark, who had been one of the "commissioners" of the resolution of 1860. These gentlemen each made one report for 1864, that of Mr. Clark containing some valuable information concerning the physical features of the northern

part of the state, but adding little or nothing to the actual geology. For a report of progress, on the first year's work, limited in time and means, the pamphlet containing these two papers may be considered a creditable production; and had the survey been continued as planned by Mr. Clark it might have become useful and successful. But it became apparent that Dr. Hanchett was not intelligently and wholly devoted to the work, and on the passage of a more general act by the Legislature of 1865, the governor conferred the position of state geologist upon Mr. Henry H. Eames.

Mr. Eames made two brief annual reports of progress, one for 1865 and one for 1866. The former is devoted to an account of a "prospecting" tour made by him through the metalliferous region bordering on lake Superior, and the latter to observations on the geology of some of the north central counties of the state. It was owing to the discoveries of Mr. Eames that the "gold fever" centering on Vermilion lake rose in speculative mining circles. This prevailed for about two years, and subsided after the Legislature refused further appropriations for the survey.

The notes and observations of Col. Charles Whittlesey, made in Minnesota at various times, sometimes for parties at private expense and sometimes for the United States government, were printed at the cost of the State of Minnesota, and issued, at Cleveland, Ohio, as a "Report of explorations in the mineral regions of Minnesota during the years 1848, 1859 and 1864," dated 1866. As a geological report this unpretentious brochure is of more value than all the previous reports, issued under the auspices of the state, combined.

In 1865 Mr. N. C. D. Taylor was authorized by act of the Legislature to make surveys for copper in the valley of the St. Croix and of the Kettle rivers, to the aggregate cost of one thousand dollars. A brief report, occupying about one octavo page, was rendered by Mr. Taylor and printed in the executive documents (for 1866?), giving an account of his operations and quoting the verbal opinion of Prof. James Hall.

In 1870 Prof. A. Winchell was appointed by the governor to examine and report on the reputed salt springs at Belle Plaine, with a view to ascertain the propriety of appropriating money to aid in the development of the brine by the State Legislature. The published report is an octavo pamphlet of sixteen pages, and was the last work of the kind done through the instrumentality of the state before the beginning of the present survey.

Those who desire a fuller account of these early surveys and of other similar work in the State of Minnesota, prior to 1872, may consult the final report of the present "geological and natural history survey," Vol. I. It is the purpose of this paper to deal more fully with the progress and history of the present survey.

*History of the Geological and Natural History survey of Minnesota.*

The law which organized this survey was drawn up by president Wm. W. Folwell, of the University of Minnesota. This law, before it was offered in the State Legislature, was shown to some geologists and educators, who might have some opinion or advice to offer as to its provisions. There is no question but one of the prime motives of the law was to introduce another auxiliary force into the state university by making it the centre whence should radiate information concerning the natural features of the state, and toward which should gravitate all collections of natural history that should otherwise be brought to light. It would furnish information, perhaps to the body of students through its officers, to the state at large, and to the country, through its reports; and in its museum would be seen the outward proofs of the resources of the state and the means for illustrating the natural sciences as they should be taught in the university. The actual and minute study of the natural history of the state was, perhaps, a secondary motive, although this is specifically required by the terms of the law. It is a comprehensive law, and was introduced into the state Senate by regent J. S. Pillsbury. Having passed both houses, it was approved by governor Horace Austin, March 1, 1872. It reads as follows:

*Law of the Minnesota survey.*

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

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

SEC. 8. It shall be the duty of the said board of regents, through their president, to make, on or before the second Tuesday in December of each and every year, a report showing the progress of the said surveys, accompanied by such maps, drawings and specifications as may be necessary and proper to exemplify the same to the governor, who shall lay the same before the Legislature; and the said board of regents upon the completion of any separate portion of the said surveys, shall cause to be prepared a memoir or final report, which

shall embody in a convenient manner all useful and important information accumulated in the course of the investigation of the particular department or portion, which report or memoir shall likewise be communicated through the governor to the Legislature.

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

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

Approved March 1, 1872.

This is the organic law of the survey, and it is still in force in all its provisions. The Legislature, in some of its subsequent sessions, passed laws to facilitate the execution of this, or amplifying some of its provisions, but in no respect has a single clause of this law been abrogated or restricted.

Although the law was passed and approved on the first day of March, the regents took no action looking to its execution till July following, when the writer was summoned to St. Paul from active field work in the State of Ohio to meet the board of regents then in session, and to assume the position of state geologist under the law. Engagements in Ohio, however, would not permit the beginning of the season's work till September.

A moment's examination of the law was sufficient to convince any geologist that the sum of money appropriated for the work was wholly inadequate to the purposes which the law contemplated; and therein it is evident that the Legislature did not so much expect the law would effect a complete survey of the state as that it would pay, in a measure, the services of an officer at the university who should be made useful in any way that the regents could find it convenient to have him work, giving particular attention to the natural sciences. The survey in this position had not an encouraging outlook, and the appointment to its head implied that the man who accepted it would either fail ignominiously or must find some way to increase the revenues that were vital to its continuance and its success. It was in view of this that the first annual report closed with the following recommendation:

*Recommendations concerning the Salt Spring lands.*

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:

*First* — It will not pay for the services of a single employé on the survey capable of working under the law. Hence, it well-nigh renders the law inoperative.

*Second* — 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.

*Third* — 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.

*Fourth* — 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.

*Fifth* — 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 those 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.

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.

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In the prosecution of the geological survey proper, after a general reconnaissance, 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 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 vested 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 the state may have either of two origins. They may be the result 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 was fortunate for the survey that at this juncture the public had become convinced, pretty generally, that the legislative aid that had been sought by the Belle Plaine salt company, and had been granted by the donation of some of the Salt Spring lands of the state, even contrary to the recommendation of the geologist who had advised against it, was a scheme to make inroads on the Salt Spring lands, more than for the *bona fide* exploitation of the brine springs that were said to exist at Belle Plaine. It was evident that unless some other use were made of this United States land-grant other enterprising communities, or mining companies, would discover salt water, or some other reasons for making inroads on this grant for aid in "developing" such suspected natural wealth. Indeed, the present writer was hardly known to have been appointed state geologist before he was requested to accompany the officers of the Belle Plaine salt company to some other part of the state in order to designate where the next deep well should be sunk for finding brine, at the expense of the Salt Spring lands. Several far-seeing public officers, it seems, at about the same time, suggested that these lands should be saved for some better purpose. Among those who had thus conferred, and had concluded that these lands might be appropriated to the maintenance of the geological and natural history survey of the state, should be mentioned Hon. A. J. Edgerton,\* then state railroad commissioner, Hon. H. B. Wilson, superintendent of public instruction, Hon. O. B. Whitcomb, state auditor, and Senator J. S. Pillsbury, one of the regents of the university. From none of these, however, did the suggestion first come to the writer, but from Mr. W. D. Hurlbut of Rochester,

\* Since United States Senator from Minnesota and Chief Justice of Dakota.

and it was almost solely through his representations that the following rough draft of a law was prepared by the state geologist, and forwarded to Hon. J. S. Pillsbury with a request that he would re-model it according to his judgment, and offer it in the state Senate the following winter. Mr. Pillsbury, however, turned it over to senator Edmund Rice of St. Paul, who introduced it *verbatim* as drafted, and it so passed both houses and was approved by the governor.

*The appropriation of the Salt Spring lands.*

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

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

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

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

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

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

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

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

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

Approved March 10, 1873.

It is reasonable to suppose that after the passage of this law all private schemes for the development of doubtful salt springs, and the reduction of the fund by misguided attempts at exploration would cease, but that was not the case. A bill was introduced in the House of Representatives at the next session of the Legislature to grant the Belle Plaine salt company more land in aid of their enterprise, requiring the board of regents to give up to that company a certain amount of the salt spring lands for every one hundred feet deeper that company should sink their well at Belle Plaine, aggregating six sections of land in all. It was duly referred to the proper committee, but was never reported for consideration by the House.

*Deficit in the Salt Spring lands.*

The Salt Spring lands originally granted the state aggregated 46,080 acres. But by various losses and state grants, and by conflicts with other United States grants, the selections made by the state not having been duly certified and recovered from the available public domain, the amount that was found capable of being used for the survey was only 18,771 acres. The officers of the United States government solely were responsible for this deficit, since governor Sibley, the first governor of the state, had complied with the law and all the terms of the grant, in having them selected.\* When this fact was represented to the state Legislature a memorial was passed, addressed to Congress, asking the privilege of making re-selections of land in the state of Minnesota sufficient to make the entire grant good to the State; such permission was granted, and twenty-four sections were added to the available land-grant of the geological survey. These, however, were not turned over to the regents for this purpose till the winter of 1885, when the Legislature passed the following:

AN ACT to transfer to the custody and control of the board of regents of the University of Minnesota the lands granted by Congress to the State by an act entitled "An act granting lands to the State of Minnesota in lieu of certain lands heretofore granted to said State," approved March third (3d), one thousand eight hundred and seventy-nine (1879) to authorize the said board to sell such lands and dispose of the proceeds of such sales.

WHEREAS, The state lands known as state salt lands, were by an act approved March tenth (10), one thousand eight hundred and seventy-three (1873), chapter one hundred and thirty-three (133), general laws of one thousand eight

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\* Compare *Miscellaneous Publications* of the survey: Report on the Salt Spring lands due the State of Minnesota; a history of all official transactions relating to them, and a statement of their amount and location. N. H. Winchell, 1874.

hundred and seventy-three (1873), transferred to the custody and control of the board of regents of the University of Minnesota, to be by said regents sold, and the proceeds thereof held in trust by them, and disbursed in accordance with the law ordering a geological and natural history survey of the State; and

WHEREAS, It was found that certain parcels of such state lands had been otherwise disposed of by the United States to actual settlers upon such lands, for which indemnity lands have since been granted to the State by an act of Congress approved March third (3), one thousand eight hundred and seventy-nine (1879); therefore

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

SECTION 1. That the lands granted by Congress to this State by an act entitled "An act granting lands to the State of Minnesota in lieu of certain lands heretofore granted to said state," approved March third (3), one thousand eight hundred and seventy-nine (1879), be and the same are hereby transferred to the custody and control of the board of regents of the University of Minnesota, which lands the said board may sell in such amounts as they may deem most expedient and beneficial, the proceeds thereof being held in trust by them, and only disbursed in accordance with the law ordering a geological and natural history survey of the State, and the said board shall make report of their doings in the premises, as provided by law.

SEC. 2. This act shall take effect and be in force from and after its passage. Approved Feb. 24, 1885.

*Publication of the annual reports.*

The Legislature of 1876 passed the following law relating to the printing of the annual reports of progress of the survey:

AN ACT relating to the printing of the reports of the board of regents of the University of Minnesota on the progress of the geological and natural history survey of the State.

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

SECTION 1. One thousand copies of that portion of the annual report of the board of regents of the University of Minnesota which embraces the report of the state geologist on the progress of the geological and natural history survey of the State shall hereafter be paged and bound separately and shall be subject to the disposition of the said board of regents.

SEC. 2. Whenever in the progress of said survey a full and final report shall be made on the geology of any of the counties of the State, five hundred extra copies of each county report so made by the board of regents shall be printed for the use of the counties so reported on; said copies being subject to the order of the county commissioners of said county.

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

Approved March 6, 1876.

The annual reports are transmitted to the governor by the regents of the university as a part of their report on the affairs of the university, and they are published as such; and the ex-

pense is provided for regularly by the *printing commission* who make estimates, in advance, of the amount of money needed for all the public printing, reporting the same to the Legislature for appropriation for the current or coming year. Of these reports sixteen have been published, one for each year since the survey began.

*Publications of the Geological and Natural History Survey of Minnesota.*

THE FIRST ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1872. 112 pp., 8 vo.; with a colored geological map of the State. By *N. H. Winchell*. Contains a list of earlier publications relating to the geology and geography of Minnesota, and a sketch of the geology of the State as known in 1872. Second edition identical with the original, 1884.

THE SECOND ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1873. 145 pp., 8 vo.; with illustrations. By *N. H. Winchell* and *S. F. Peckham*.

THE THIRD ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1874. 42 pp., 8 vo.; with two county maps. By *N. H. Winchell*.

THE FOURTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1875. 162 pp., 8 vo.; with four county maps and a number of other illustrations. By *N. H. Winchell*, assisted by *M. W. Harrington*.

THE FIFTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1876. 248 pp., 8vo.; four colored maps and several other illustrations. By *N. H. Winchell*, with reports on Chemistry by *S. F. Peckham*, Ornithology by *P. L. Hatch*, Entomology by *Allen Whitman*, and on Fungi by *A. E. Johnson*.

THE SIXTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1877. 226 pp. 8vo.; three geological maps and several other illustrations. By *N. H. Winchell*, with reports on Chemical Analysis by *S. F. Peckham*, on Ornithology by *P. L. Hatch*, on Entomology by *Allen Whitman*, and on Geology of Rice county by *L. B. Sperry*.

THE SEVENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1878. 123 pp., 8vo.; with twenty-one plates. By *N. H. Winchell*, with a field report by *C. W. Hall*, Chemical Analyses by *S. F. Peckham*, Ornithology by *P. L. Hatch*, a list of the plants of the north shore of lake Superior by *B. Juni*, and an Appendix by *C. L. Herrick* on the Microscopic Entomostraca of Minnesota (twenty-one plates).

THE EIGHTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1879. 183 pp., 8vo.; one plate (Castoroides). By *N. H. Winchell*. Containing a statement of the methods of Microscopic Lithology, a discussion of the Cupriferous Series

in Minnesota, and descriptions of new species of brachiopoda from the Trenton and Hudson River formations; with reports on the Geology of Central and Western Minnesota, by *Warren Upham*; on the lake Superior region, by *C. W. Hall*; lists of Birds and of Plants from Lake Superior, by *Thomas S. Roberts*; Chemical Analyses by *S. F. Peckham*; report by *P. L. Hatch*; and four Appendixes.

THE NINTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1880. 392 pp., 8 vo.; three appendixes, two wood cut illustrations, and six plates. By *N. H. Winchell*. Containing field descriptions of 442 crystalline rock samples, and notes on their geological relations, from the northern part of the state; new brachiopoda; the water supply of the Red River Valley, and simple tests of the qualities of water; with reports on the Upper Mississippi region, by *O. E. Garrison*; on the Hydrology of Minnesota, by *C. M. Terry*; on the Glacial Drift and its Terminal Moraines, by *Warren Upham*; Chemical Analyses by *J. A. Dodge*; a list of the Birds of Minnesota, by *P. L. Hatch*; and of the Winter Birds, by *Thomas S. Roberts*.

THE TENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1881. 254 pp., 8 vo.; with ten wood cut illustrations, and fifteen plates. By *N. H. Winchell*. Containing field descriptions of about 400 rock samples, and notes on their geological relation, continued from the last report; the Potsdam sandstone; typical thin sections of the rocks of the Cupriferos Series; and the deep well at the "C" Washburn mill, Minneapolis; with Geological notes by *J. H. Kloos*; Chemical Analyses by *J. A. Dodge*; and papers on the Crustacea of the fresh waters of Minnesota (eleven plates), by *C. L. Herrick*.

THE ELEVENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1882. 219 pp., 8 vo.; with three wood cut illustrations and one plate. By *N. H. Winchell*. Containing a report on the Mineralogy of Minnesota, and a note on the Age of the rocks of the Mesabi and Vermilion iron districts; with papers on the Crystalline rocks of Minnesota, by *A. Streng* and *J. H. Kloos*; on Rock outcrops in Central Minnesota, and on lake Agassiz, by *Warren Upham*; on the Iron region of Northern Minnesota, by *Albert H. Chester*; Chemical Analyses by *J. A. Dodge*; and an Appendix containing Minnesota Laws relating to Mines and Mining, abstracted by *C. L. Herrick*.

THE TWELFTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1884. Summary report, containing palæontological notes, and a paper on the comparative strength of Minnesota and New England granites, 26 pages, by *N. H. Winchell*; final report on the Crustacea of Minnesota included in the orders Cladocera and Copepoda. 192 pages and 30 plates, by *C. L. Herrick*, and a catalogue of the flora of Minnesota, 193 pages, with ore map showing the forest distribution, by *Warren Upham*.

THE THIRTEENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1884. 196 pages. Geological reconnoissances, the Vermilion iron ores, the crystalline rocks of Minnesota, and of the Northwest, the Humbolt salt well in Kittson county, records of various deep wells in the State, fossils from the red

quartzite at Pipestone, reports on the New Orleans Exposition and on the General Museum, by *N. H. Winchell*; Geology of Minnehaha county, Dakota, by *Warren Upham*; Chemical report by *Prof. James A. Dodge*; Minnesota geographical names derived from the Dakota language by *Prof. A. W. Williamson*; insects injurious to the cabbage, by *O. W. Oestlund*; Geological notes in Blue Earth county, by *Prof. A. F. Bechdolt*, and on a fossil elephant from Stockton by *Prof. John Holzinger*; papers on the Cretaceous fossils in the boulder clays in the Northwest by *George M. Dawson*, and by *Woodward* and *Thomas*, and notes on the Mammals of Big Stone Lake and vicinity by *C. L. Herrick*.

THE FOURTEENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1885. 354 pp.; two plates of fossils and two wood cuts. Containing summary report, notes on some deep wells in Minnesota, descriptions of four new species of fossils, a supposed natural alloy of copper and silver from the north shore of lake Superior, and revision of the stratigraphy of the Cambrian in Minnesota, with the following papers by assistants, viz.: List of the Aphididæ of Minnesota, with descriptions of some new species, by *O. W. Oestlund*; Report on the Lower Silurian Bryozoa, with preliminary descriptions of some new species, by *E. O. Ulrich*; Conchological notes by *U. S. Grant*; Bibliography of the Foraminifera, recent and fossil, by *Anthony Woodward*.

THE FIFTEENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1886. 493 pp., 8vo.; 120 diagram illustrations and sketches in the text, and two colored maps; embracing reports on observations on the crystalline rocks in the northeastern part of the state, by *Alexander Winchell*, *N. H. Winchell* and *H. V. Winchell*; Chemical report by *Prof. J. A. Dodge*; additional railroad elevation, by *N. H. Winchell*; list of Minnesota geographical names derived from the Chippewa language, by *Rev. J. A. Gilfillan*, and notes on Illæni, describing three new species, by *Aug. F. Foerste*.

THE SIXTEENTH ANNUAL REPORT ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, FOR THE YEAR 1887. 504 pp.; two plates, one map and eighty-eight other illustrations. Contains observations in the area of the original Huronian by the state geologist and by *Alexander Winchell*; also on the Marquette, the Gogebic and the Penokee iron regions; also reports on further observations in the northeastern part of the State, by the same; also a report by *Horace V. Winchell* on the region of the Big Fork and Little Fork rivers, and Rainy lake; also notes on the molluscan fauna of the state by *Uly S. Grant* and *John M. Holzinger*.

*The publication of the Final Report.*

The Legislature of 1885 also made provision for the publication of the final report of the survey by the enactment of the following general law.

AN ACT relating to the publication of the report of the geological and natural history survey of the State.

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

SECTION 1. The governor, the secretary of state and the state geologist are hereby created a commission for the printing and publication of the reports of the regents of the university on the geological and natural history survey of the State.

SEC. 2. It shall be their duty to supervise the printing of the final reports of said survey, and the engraving of the accompanying maps and illustrations, in such style and manner as they shall determine and judge best calculated to exhibit to the people of the State, the natural resources of the State as required by the law creating the geological and natural history survey.

SEC. 3. They shall cause to be republished in the same manner the third (3d), fourth (4th) and fifth (5th) reports of progress of said survey, at as early a date as practicable, in an edition of two thousand copies.

SEC. 4. The volumes of the final report of said survey, as they may be prepared by the state geologist from time to time, shall be issued in an edition of five thousand (5,000) copies each, and shall be distributed, in the name of the board of regents of the university, under the direction of the state geologist, to scientific and educational institutions, and to individuals, as follows: To the library of each chartered college and scientific institution in Minnesota, three (3) copies each; to each normal school, three (3) copies; to the libraries of the institute for the deaf and mute, the insane asylums, the state prison, and every public library in the state not otherwise designated, one (1) copy each; to each of the offices in the capitol, one (1) copy; to each member of the board of regents, three (3) copies; to the library of the state university two hundred (200) copies; to the Historical Society, and to the Minnesota academy of sciences, ten (10) copies each; to each newspaper published in the State, one (1) copy each; to each senator and representative of the present Legislature, one (1) copy; to the governor and lieutenant governor, each one (1) copy; to each assistant on the survey who has furnished manuscript or illustrations published in the report, three (3) copies; to the general office of each railroad that has furnished aid to the survey, three copies; to the library of each high school, furnishing students fitted for the freshman class of the state university, one (1) copy; to the state library of each state in the Union, one (1) copy; to each state university and each college of agriculture and mechanic arts, one (1) copy; to geologists and naturalists of Minnesota, fifty (50) copies; to the geologists and naturalists of other states, two hundred (200) copies; to other colleges and scientific institutions in the United States, one hundred (100) copies; to foreign institutions and scientists, one hundred (100) copies; and to the state geologist, twenty-five (25) copies. The remainder shall be deposited in the state university, and shall be sold at such prices as the board of regents may determine, and the proceeds of



such sales shall be used by said regents for the purchase of apparatus and books for the survey, and after its completion, for the departments of natural science at the state university.

SEC. 5. The expense of printing, engraving, binding and distribution of said reports shall be paid out of any moneys not otherwise appropriated, in the state treasury, on warrants of the state auditor approved by the governor and secretary of state.

SEC. 6. The commissioners hereby appointed shall perform the duties herein designated without further compensation than the payment of the actual expenses incurred in the discharge thereof.

SEC. 7. This act shall take effect and be in force from and after its passage.  
Approved March 7, 1885.

Before this law took effect the first volume of the final report had been printed and the second was well under way of publication. The final report is ordered by the same law that orders the annual reports, and every provision that can be construed for the publication of the latter is binding for the former. This view was held by the standing printing commission, and when the regents tendered Vol. I. of the final report the secretary of state gave orders for its publication as one of the documents of the state. Still, inasmuch as there might be a difference of opinion as to the binding obligation on the proper officers to make provision for the final report, it was declared in the foregoing law that such volumes *shall be issued and shall be distributed and that the expense of printing, engraving, and distribution shall be paid out of any moneys not otherwise appropriated in the state treasury.* Thus the publication of the results of the survey is made a regulated function of the printing bureau of the state, and can no more be omitted, in the plans for publishing the documents of the state, without neglect of duty, than can any others of the state documents which by law are required to be presented to the governor.

In accordance with this law the same Legislature appropriated twelve thousand dollars intended to cover the expense of publishing volumes II. and III. of the final report. But, by a curious proviso such as sometimes creep into laws passed in the hurried manner of modern American legislation, this fund was required to be expended by the regular commissioners of printing, and not by the special commission which was created for the publication of the final report. The appropriation was found to be but little more than sufficient for publishing one of the volumes (Vol. II.), and that was issued in the fall of 1888. The final report of the survey, so far as published, is described as follows:

OFFICE COPY  
PLEASE RETURN TO:  
GEOLOGICAL SURVEY

THE GEOLOGY OF MINNESOTA. VOL. I. OF THE FINAL REPORT. 1872-1882. xiv. and 697 pp., quarto; illustrated by 43 plates and 52 figures. By *N. H. Winchell*, assisted by *Warren Upham*. Containing an historical sketch of explorations and surveys in Minnesota, the general physical features of the state, the building stones, and the Geology of Houston, Winona, Fillmore, Mower, Freeborn, Pipestone, Rock and Rice counties, by *N. H. Winchell*; the Geology of Olmsted, Dodge and Steele counties, by *M. W. Harrington*; and the Geology of Waseca, Blue Earth, Faribault, Watonwan, Martin, Cottonwood, Jackson, Murray, Nobles, Brown, Redwood, Yellow Medicine, Lyon, Lincoln, Big Stone, Lac qui Parle and Le Sueur counties, by *Warren Upham*. Distributed gratuitously to all public libraries and county auditors' offices in the state, to other state libraries and state universities, and to leading geologists and scientific societies; the remainder are held for sale at the cost of publication, \$3.50 per copy in cloth, or \$5 in grained half roan binding upon application to Prof. N. H. Winchell, Minneapolis.

THE GEOLOGY OF MINNESOTA. VOL. II. OF THE FINAL REPORT. 1882-1885. xxiv. and 695 pp., quarto; illustrated by 42 plates and 32 figures. By *N. H. Winchell*, assisted by *Warren Upham*, containing chapters on the Geology of Wabasha, Goodhue, Dakota, Hennepin, Ramsey and Washington counties, by *N. H. Winchell*, and on Carver, Scott, Sibley, Nicollet, McLeod, Renville, Swift, Chippewa, Kandiyohi, Meeker, Wright, Chisago, Isanti, Anoka, Benton, Sherburne, Stearns, Douglas, Pope, Grant, Stevens, Wilkin, Traverse, Otter Tail, Wadena, Todd, Crow Wing, Morrison, Mille Lacs, Kanabec, Pine, Becker and Clay counties, by *Warren Upham*. Distributed according to law in the same manner as Vol. I. above.

*The Bulletins of the Survey.*

The Legislature of 1885 enacted the following law, requiring the state geologist to make actual explorations by drilling or digging, for the discovery of economic products, and providing for the publication of the reports of such discoveries, and of other scientific contributions:

AN ACT to extend the work of the geological and natural history survey of the State.

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

SECTION 1. It shall be the duty of the state geologist, to make practical and actual tests by drilling or digging or other excavation in the earth, such as he shall deem best suited to accomplish the purpose of this bill, for the discovery of any of the hidden mineral resources of the state, such as iron, copper, silver, gold, coal, gas, coal-oil, common salt, or any other valuable material that he may deem likely to exist in any of the rock strata of the state.

SEC. 2. In determining the localities at which such testing and exploring shall be done he shall be guided by such geological facts as he may possess or may obtain, which may indicate the existence of any of the substances which it is the purpose of this act to discover. He shall also be guided by the proportionate amount of money that the owner, or owners, of the land on which such exploration may be proposed, shall contribute to pay the cost of such exploration.

SEC. 3. It shall be the duty of the state geologist to report at once to the board of regents all discoveries, either of economic or scientific interest to the state, that may be made by such testing and exploration. Such report shall be published by the board of regents in the same manner as now provided for the publication of the annual reports of the geological and natural history survey of the state, and shall be paid for by the same fund; *provided*, that any important mineral discoveries, or other scientific contributions to the geological and natural history survey, that the said state geologist may deem necessary for immediate publication, shall not be suppressed until the regular report of the board of regents, but shall be issued from time to time under the direction of said state geologist.

SEC. 4. That the sum of five thousand (5,000) dollars for the year A. D. one thousand eight hundred and eighty-seven (1887) and the sum of five thousand (5,000) dollars for the year A. D. one thousand eight hundred and eighty-eight (1888) is hereby appropriated out of any moneys not otherwise appropriated for the purpose of defraying the expense of said tests. The investigations provided for in this act shall not be conducted in the interest of any mining company or corporation.

SEC. 5. This act shall take effect and be in force from and after its passage.  
Approved March 8th, 1887.

In accordance with this law it was deemed best to establish a series of minor publications or "bulletins," which might be issued from time to time, at longer or shorter intervals, and the following have appeared:

#### BULLETINS.

- No. 1. History of Geological Surveys in Minnesota. By *N. H. Winchell*.
- No. 2. Preliminary Description of the Peridotites, Gabbros, Diabases and Andesytes of Minnesota. By *M. E. Wadsworth*.
- No. 3. Report of work done in Botany in the year 1886. By *J. C. Arthur*.
- No. 4. A Synopsis of the Aphididæ of Minnesota. By *O. W. Oestlund*.
- No. 5. Natural Gas in Minnesota. By *N. H. Winchell*.

#### *Miscellaneous publications.*

These embrace some circulars and announcements that were designed in the earlier years of the survey, to bring to the public attention some of the plans and needs of the survey, in which the co-operation and assistance of interested individuals were necessary. Most of them contain nothing of scientific value, and but small editions were printed. They are the following:

1. CIRCULAR NO. 1. A copy of the law ordering the survey, and a note asking the co-operation of citizens and others. 1872.
2. PEAT FOR DOMESTIC FUEL. 1874. Edited by *S. F. Peckham*.
3. REPORT ON THE SALT SPRING LANDS DUE THE STATE OF MINNESOTA. A history of all official transactions relating to them, and a statement of their amount and location. 1874. By *N. H. Winchell*.

4. A CATALOGUE OF THE PLANTS OF MINNESOTA; prepared in 1865 by *Dr. I. A. Lapham*, contributed to the Geological and Natural History Survey of Minnesota, and published by the State Horticultural Society in 1875.
5. CIRCULAR No. 2. Relating to botany, and giving general directions for collecting information on the flora of the State. 1876.
6. CIRCULAR No. 3. The establishment and organization of the Museum. 1877.
7. CIRCULAR No. 4. Relating to duplicates in the Museum and exchanges. 1878.
8. THE BUILDING STONES, CLAYS, LIMES, CEMENTS, ROOFING, FLAGGING AND PAVING STONES OF MINNESOTA. A special report by *N. H. Winchell*. 1880.
9. CIRCULAR No. 5. To Builders and Quarrymen. Relating to the collection of two-inch cubes of building stones for physical tests of strength, and for chemical examination, and samples of clay and brick for the general museum. 1880.
10. CIRCULAR No. 6. To owners of mills and unimproved water-powers. Relating to the Hydrology and water-powers of Minnesota. 1880.

The cost of these publications cannot be stated definitely. They have all been printed by the state contractor for public printing at the rates ruling for "printing of the third class," which is let to the lowest bidder by the standing printing commission consisting of the secretary of state, the state auditor, and the state treasurer. The price varies from year to year. The engraving is estimated and contracted for separately as required. The edition of the annual reports and the bulletins is 2,400 copies and of the final report 5,000 copies. The former are distributed gratuitously, and the latter are sold at \$3.50 and \$5.00 per volume according to style of binding and quality of paper, though of the latter a generous free distribution is made to libraries and scientists.

#### *Museum and Library.*

The General Museum of the university is the outgrowth of the survey. It is stored in the university buildings. Its equipment as well as maintenance is wholly derived from the survey fund. It is a means of instruction to the students in natural science and of enlightenment and pleasure to all visitors. The last report (17th) gave the entries in the geological and mineralogical department 6827, and in the zoological 1633, embracing several times as many specimens. In archæology the entries number 198. Besides these, several valuable collections have been deposited by their owners for temporary exhibition and safe-keeping. The rooms are well-warmed and furnished with secure cases for all specimens.

The library of the survey contains perhaps one thousand books and pamphlets, obtained by exchange and by purchase. It is stored in the office of the state geologist at the university and is used only by the officers of the survey or by students specially interested. It is not a public library and has no regulations for its use.

*Cost of the Survey proper.*

When the survey began it had an annual appropriation of one thousand dollars. This was increased to two thousand at the first meeting of the Legislature, and five hundred dollars were also appropriated for chemical apparatus for the survey. The cash appropriation of two thousand dollars per year was to continue till the revenue from the Salt Spring lands amounted to that sum and was discontinued in 1879. The Salt Spring lands, aggregating, with the deficit afterward secured from Congress, the sum of 38,643 acres, which could not, in accordance with the terms of existing law, be sold for less than five dollars per acre, were placed in the hands of the regents by the same Legislature to carry on the survey. This gave at once a prospective aggregate net sum of \$193,215 with which the survey should be carried on in its various branches.

The reports of the treasurer of the university have been consulted for facts respecting the receipts and expenditures of the regents for the survey, and they show the following results. This record is complete to July 31, 1888, the date of the last fiscal statement of the university :

*Sums reported received by the university treasurer for the geological survey.*

Oct. 2, 1872.	Cash from the state treasurer.....	\$1,000.00
June 16, 1873.	“ “ “ .....	2,500.00
Aug. 13, 1874.	“ “ “ .....	2,000.00
June 5, 1875.	“ “ “ .....	2,000.00
June (?), 1876.	“ “ “ .....	2,000.00
July 1877.	“ “ “ .....	2,000.00
Apr. 5, 1878.	“ “ “ .....	1,000.00
June 26, 1878.	“ “ “ .....	1,000.00
Oct. 30, 1878.	Cash sale of Salt Spring land (balance).....	2,893.64
Dec. 1879.	“ from state treasurer .....	2,000.00
Feb. 5, 1880.	“ sales of Salt Spring land .....	3,140.44
Apr. 24, 1880.	“ “ “ .....	957.92
Apr. 24, 1880.	“ “ “ .....	390.00
July 2, 1880.	“ “ “ .....	941.23
Aug. 5, 1880.	“ “ “ .....	67.40

Aug. 7, 1880.	Cash sales of Salt Spring land.....	17.73
Dec. 10, 1880.	“ “ “ .....	1,138.17
Dec. 10, 1880.	“ “ “ .....	170.00
Jan. 26, 1881.	“ “ “ .....	18.84
June 28, 1881.	“ “ “ .....	941.23
July 13, 1881.	“ “ “ .....	146.48
July 25, 1881.	“ “ “ .....	17.73
Oct. 29, 1881.	“ “ “ .....	1,009.36
Nov. 10, 1881.	“ “ “ .....	25.16
Jan. 16, 1882.	“ “ “ .....	25.00
May 26, 1882.	“ “ “ .....	598.45
June 20, 1882.	“ “ “ .....	693.90
June 24, 1882.	“ “ “ .....	152.32
June 24, 1882.	“ “ “ .....	152.32
June 24, 1882.	“ “ “ .....	152.32
June 24, 1882.	“ “ “ .....	151.13
June 24, 1882.	“ “ “ .....	285.60
June 24, 1882.	“ “ “ .....	47.60
July 1, 1882.	“ “ “ .....	1,083.58
July 6, 1882.	“ “ “ .....	539.70
July 21, 1882.	“ “ “ .....	951.21
Aug. 4, 1882.	“ “ “ .....	775.19
Dec. 5, 1882.	“ “ “ .....	919.21
Dec. 27, 1882.	“ “ “ .....	11.90
Jan. 18, 1883.	“ “ “ .....	975.00
Feb. 9, 1883.	“ “ “ .....	170.00
Feb. 14, 1883.	“ “ “ .....	1,238.15
Mar. 10, 1883.	“ “ “ .....	116.40
Mar. 13, 1883.	“ “ “ .....	231.43
Apr. 17, 1883.	“ “ “ .....	215.60
June 9, 1883.	“ “ “ .....	764.32
June 28, 1883.	“ “ “ .....	228.48
June 30, 1883.	“ “ “ .....	322.43
July 7, 1883.	“ “ “ .....	1,116.13
July 14, 1883.	“ “ “ .....	246.68
July 16, 1883.	“ “ “ .....	2,176.00
July 26, 1883.	“ “ “ .....	600.00
Nov. 22, 1883.	“ “ “ .....	50.55
Jan. 10, 1884.	“ “ “ .....	581.94
Feb. 19, 1884.	“ “ “ .....	539.70
May 15, 1884.	“ “ “ .....	240.00
June 7, 1884.	“ “ “ .....	325.20
July 3, 1884.	“ “ “ .....	550.91
July 12, 1884.	“ “ “ .....	597.06
Aug. 6, 1884.	“ “ “ .....	91.98
Oct. 6, 1884.	“ “ “ .....	527.10
Oct. 18, 1884.	“ “ “ .....	210.50
Oct. 22, 1884.	“ “ “ .....	687.67
Nov. 5, 1884.	“ “ “ .....	187.66

Apr. 22, 1885.	Cash sales of Salt Spring land.....	116.90
June 16, 1885.	“ “ “ .....	546.00
June 23, 1885.	“ “ “ .....	288.70
June 30, 1885.	“ “ “ .....	212.50
July 6, 1885.	“ “ “ .....	550.91
July 8, 1885.	“ “ “ .....	758.71
Sept. 3, 1885.	“ “ “ .....	467.50
Sept. 23, 1885.	“ “ “ .....	71.04
Oct. 24, 1885.	“ “ “ .....	81.85
Oct. 26, 1885.	“ “ “ .....	787.40
Nov. 16, 1885.	“ “ “ .....	121.00
Nov. 24, 1885.	“ “ “ .....	421.44
Mar. 31, 1886.	“ “ “ .....	1,372.41
Apr. 6, 1886.	“ “ “ .....	217.50
May 22, 1886.	“ “ “ .....	780.50
June 24, 1886.	“ “ “ .....	84.00
July 17, 1886.	“ “ “ .....	39.90
July 2, 1886.	“ “ “ .....	71.62
July 10, 1886.	“ “ “ .....	244.92
July 20, 1886.	“ “ “ .....	494.50
July 27, 1886.	“ “ “ .....	56.41
Oct. 20, 1886.	“ “ “ .....	187.20
Oct. 22, 1886.	“ “ “ .....	1,537.09
Nov. 4, 1886.	“ “ “ .....	68.20
Nov. 10, 1886.	“ “ “ .....	194.80
Apr. 15, 1887.	“ “ “ .....	25.20
June 7, 1887.	“ “ “ .....	68.91
June 21, 1887.	“ “ “ .....	56.40
June 23, 1887.	“ “ “ .....	152.40
July 8, 1887.	“ “ “ .....	71.46
July 20, 1887.	“ “ “ .....	476.00
Aug. 18, 1887.	“ “ “ .....	75.38
Oct. 13, 1887.	“ “ “ .....	23.28
Oct. 29, 1887.	“ “ “ .....	1,976.98
Nov. 21, 1887.	“ “ “ .....	45.00
Jan. 27, 1888.	“ “ “ .....	640.00
Jan. 27, 1888.	“ “ “ .....	172.50
Feb. 27, 1888.	“ “ “ .....	19.33
Feb. 29, 1888.	“ “ “ .....	25.35
Mar. 13, 1888.	“ “ “ .....	1.00
Mar. 22, 1888.	“ “ “ .....	139.20
June 20, 1888.	“ “ “ .....	7.00
July 2, 1888.	“ “ “ .....	71.69
July 3, 1888.	“ “ “ .....	476.00
July 7, 1888.	“ “ “ .....	75.38
July 3, 1888.	“ “ “ .....	71.46
July 14, 1888.	“ “ “ .....	200.00
July 31, 1888.	“ “ “ .....	56.40
Total receipts for the survey to July 31, 1888.....		\$61,605.07

Of this sum \$15,000 were received from the state treasurer as proceeds from the laws of 1872 and 1873, making direct cash appropriation for its support, and the rest, or \$46,105.07, has been derived from the sales of the Salt Spring lands.

The expenses of the survey, including the General Museum as reported by the regents through the university treasurer, from 1872 to July 31, 1888, amount to \$81,061.89, making, for seventeen years, an annual expense of \$4,768.34, and showing the Salt Spring fund indebted to the university \$19,456.82.

In the treasurer's account with the survey fund, however, are numerous items charged which were incurred for the department of instruction in the university, which was for some years in the charge of the state geologist, which expenses can only by the broadest construction of the law of the survey, be considered as promoting the work of the survey. These aggregate the sum of \$12,510.80, and would reduce the total cost of the survey proper and the General Museum to \$68,551.09, and to an annual cost of \$4,032.41.

But, *per contra*, the survey has reaped substantial benefits from its association with the university. It has office and storage rooms, and laboratories in the university buildings free of rent, and access to libraries and apparatus that to gather together, or to consult elsewhere, would be at great expense.

The geological and natural history survey is one of the important wards of the university, and is constantly demonstrating the wisdom of the law that made it one of its functions to conduct it. The mutual benefits that spring from this relationship need not be dwelt upon here.

#### *Administration.*

The regents manage the sales of the Salt Spring lands. In this they are limited in their judgment only by the state law that requires that no state land shall be sold for less than five dollars per acre.

The administration of the survey proper has been almost wholly in the hands of the state geologist. He lays such plans as he chooses, governed by his own appreciation of the financial, economic, scientific and educational circumstances that may be influenced by them. These plans have almost always been submitted to the regents, or to their executive committee, prior to their execution, for their formal approval. In some instances, certain public or wide-spread want for information, expressed in corre-



spondence, or in the public press, such as the demand for information concerning the grasshopper-plague and the ways and means for alleviating the evil, the call for peat-fuel on the woodless prairies, the ravages of insects injurious to horticulture, the general belief in the existence of coal in the state or of mineral wealth in the northern part of the state, the demand for authoritative statements founded on scientific data, touching the nature and extent of our forests, or the quality of our soils, or the water used for domestic purposes, or the probability of brine for the manufacture of salt, or the existence of the necessary conditions for artesian water or burning-gas, or the quality of our native building stones,—these have all been elements that have influenced the plans formed from year to year. While answering these purposes as nearly as possible, the survey has been rendered useful to numerous individuals by private correspondence, preventing the useless expense of ill-guided exploration in many instances, and directly influential in promoting economic industry by advising expenditures where a reasonable expectation existed of remunerative results. Individual instances need not be mentioned.

This economic side of the survey has been kept in mind constantly, though it has not been made conspicuous. This was politic as well as just. The annual reports embody common patent facts, and description cast in a semi-scientific mould. They are addressed primarily to a home constituency, in order to show them the utility of the work of the survey. As the survey becomes grounded in the good will of our own citizens it is strengthened for doing more advanced work, and at the same time finds a constituency that is ready to welcome more strictly scientific publications. It is highly probable that if such a moderate course had not been pursued, the Legislature, instead of always manifesting a good will and determination to have the work well sustained, would have refused the financial aid that has been asked of it, and the work might have had the short-lived existence that has been the fate of so many other state surveys.

*Personnel of the survey.*

N. H. Winchell, state geologist .....	1872	—
Warren Upham, assistant geologist.....	1879-1885	
C. W. Hall, assistant geologist.....	1878-1880	
C. M. Terry, laboratory assistant.....	1879-1881	
O. E. Garrison.....	Occasional field assistant	
P. L. Hatch, ornithologist.....	1876	—
C. L. Herrick, zoological collector and laboratory assistant in charge of Mammals.....	1876-1885	
L. B. Sperry, geological assistant.....	1877	
P. B. Rose, chemist.....	1873	
S. F. Peckham, chemist.....	1873-1880	
Jas. A. Dodge, chemist.....	1881	—
M. W. Harrington, assistant geologist.....	1875	
Allen Whitman, entomologist.....	1876-1878	
Benj. Juni, Botanical and field assistant.....	1878	
P. P. Furber, field assistant.....	1873	
C. E. Chatfield, field assistant.....	1873	
W. E. Leonard, botanical and field assistant.....	1875	
Horace V. Winchell, field geologist and laboratory assistant.....	1881, 1885	—
Albert H. Chester, report on the iron region.....	1882	
Leo Lesquereux, palæobotanist.....	1883, 1886	
O. W. Oestland, entomologist and laboratory assistant.....	1885	—
U. S. Grant, conchology and field geologist.....	1885-1888	
J. C. Arthur, botanist.....	1885-1888	
E. O. Ulrich, bryozoans.....	1885	—
F. L. Washburn, assistant in ornithology.....	1885	
A. Woodward, } B. W. Thomas, }	Foraminifera of the Cretaceous.....	1886-1889
Frank N. Stacy, field assistant.....	1886-1887	
A. W. Jones, field assistant.....	1886	
Alexander Winchell, assistant geologist.....	1886-1887	
A. D. Meeds, field assistant.....	1888	
M. E. Wadsworth, assistant geologist.....	1886	
L. W. Bailey, Jr., botany.....	1886	
E. W. D. Holway, botany.....	1886	
W. F. Trussell, field assistant.....	1887	
H. W. Fairbanks, field assistant.....	1887	
S. W. Ford, draughtsman.....	1887	
W. D. Willard, field assistant.....	1888	

The selection of these men has been made by the state geologist, but their appointment has always been passed on by the regents or by their executive committee. The only guide in making the selections, aside from availability and fitness for the work, has been the clause in the general law requiring the employment of students and graduates of the University of Minnesota when such can be found qualified for the work, and a general enactment of the regents to the effect that the professor of chemistry at the university is, by virtue of his position, to be the chemist of the survey.

These men have not been continuously employed, even for the time expressed above, except in the case of the state geologist, Warren Upham, C. M. Terry, and O. W. Oestlund, but they have been engaged during the season of field-work or to perform some specific work for which they had such compensation as the service demanded.

The salary of the state geologist is \$2,400.

The salary of Warren Upham was \$1,200.

The salary of C. M. Terry was \$1,200.

The salary of O. W. Oestlund is \$900.

The salary of C. L. Herrick was from \$600 to \$1,200.

The chemist is paid a per centum of schedule prices for work he does for the survey. Dr. P. L. Hatch, the ornithologist, is working for the survey from pure love of birds, and asked only the payment of his field and traveling expenses. Other employes have been paid by the month from fifty to two hundred dollars, or by the job.

#### *Co-operation of the U. S. Coast and Geodetic Survey.*

Congress some years ago authorized the United States Coast and Geodetic survey to co operate with the state geological surveys in the triangulation and correct mapping of those states in which the State Legislatures may have provided for such geological and topographical surveys. Several of the States having thus been aided by the Coast and Geodetic survey, the attention of Gov. L. F. Hubbard was called to the matter by the writer in a letter dated March 19, 1884, asking him to make, or authorize to be made, a formal application to the superintendent of the Coast survey for similar aid to the Minnesota survey. Such a request was forwarded to the superintendent, and, on the appropriation by Congress of a small sum specifically for the purpose, a system of triangulation was begun at the university

under the direction of major C. O. Boutelle. This has been continued by Prof. W. R. Hoag, and has resulted in the accurate establishment of many prominent objects in the topography, referred to a base line situated between Minneapolis and St. Paul. In general the present design is to make connection at La Crosse, with the earlier triangulation carried on by the Coast survey across the state of Wisconsin. By means of this triangulation Prof. Hoag made an accurate measurement of the gorge of the Mississippi river between Fort Snelling and the brink of the Falls of St. Anthony, and prepared a map of the gorge itself. By employing the determination of latitude and longitude of the smaller cupola of the university by the Lake survey, under Gen. C. B. Comstock\* in 1873, the latitude and longitude of any point covered by the triangulation can be computed.

The result of this triangulation will be felt in the future more appreciatively than at the present time. It necessarily goes slowly, in consequence of the exactness demanded by the nature of the work. It will be for the State to supplement this triangulation with topographic work suitable for the construction of outline and contour or other topographic maps. This is what the geological survey will have to do by and by. Strictly, a topographic map should precede the geological. But in the case of Minnesota much of the state had been mapped geologically before the commencement of careful topographic mapping. This is less to be regretted in a state like Minnesota, where a large portion of the area is nearly flat, and where already the United States township survey had preceded and had furnished a series of maps that are tolerably correct. It could not be avoided, however, since the geological survey could not wait for the uncertain action of Congress, on a question which had not then been brought to its attention. Whatever errors there may be found in the future in the published geological maps of the survey can be corrected readily by reference to the topographic map of the state by counties, that is to be, based on the triangulation by the United States Coast and Geodetic survey. Two of the eastern States (Massachusetts and New Jersey) are actively engaged in this final topographic mapping, that of New Jersey being nearly complete.

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\* See the fourth annual report, p. 5.

*Benefits resulting from the survey.*

Of these it were more appropriate that some one else should write. If no mention be made here of the invisible benefits that result to the state, and particularly to the university by the prosecution of this survey, it will perhaps be proper to enumerate some of the tangible beneficial results that have accrued to the people of the state directly through the agency of the survey.

1. Beginning with the commencement of the survey the first that should be mentioned is the fact that the professorship of geology and mineralogy in the university, with the added work of instruction in botany and zoology, was maintained six years solely at the expense of the survey fund. This also includes much of the equipment, cases, maps and apparatus of that department. The same fund has also placed several hundred dollars worth of books in the general library of the university.

2. The *Salt Spring lands* of the state were saved from being gradually devoured by such enterprises as that of the Belle Plaine Salt company, and were appropriated, through the direct interposition of the survey at a critical juncture, to the prosecution of this far-reaching public enterprise.

3. On the discovery, after a laborious investigation of the official records, of the fact that the State was still entitled to a large additional amount of land under the original grant, the initial efforts of the state geologist were successful in obtaining from the United States, about fifteen thousand acres of indemnity lands which have since been devoted by the Legislature to the support of the survey.

4. The General Museum of the University is one of the tangible beneficial results of the survey.

5. There was a wide-spread belief among the citizens in the southern part of the state, prevalent when the survey began, that workable coal of the age of that found in Iowa could be discovered by making the proper exploration, and individuals had incurred considerable expense in looking for it. One of the first efforts of the survey was to settle this question; and the published result of such investigation went far toward stopping further useless expenditure of money.

6. The agitation of this subject by unscrupulous prospectors and well-drillers culminated in a proposed law, which was introduced in the Legislature of 1883 (?) offering a reward of twenty thousand dollars for the discovery, in the state, of "coal" in work-

able quantities. This law was so drawn that it did not discriminate as to the age or the quality of the coal to be discovered, and any one familiar with the Cretaceous lignites of the state, could have made a legitimate demand for the reward within sixty days after the adjournment of the Legislature. Through the agency and advice of the state geologist this law was adversely reported by the committee having it in charge. It is only on the principle of "a penny saved is two pence gained" that this can be claimed as one of the tangible effects of the survey.

7. A similar law ordering the appointment of a "commissioner of peat," at a salary of two thousand dollars per year, was also defeated in the State Legislature, largely through the influence of the survey in 1874.

8. A law ordering the donation of further subsidy to the Belle Plaine salt company, and another for the investigation of the grasshopper-plague, and another appointing a state mineralogist with special reference to supposed great wealth of the state in gold and silver, each looking to the unguided expenditure of the revenues of the state, were severally proposed in the State Legislature, and were either rejected or shown to be unnecessary by the existence and the agency of the survey.

9. In the prosecution of the regular work of the survey general attention has been called to the economic resources of the state. The survey has been directly instrumental either in investigating in the first instance, or in guiding by counsel when once begun, nearly all the industries of the state that arise from the rocky substructure. This has been done officially and by private correspondence. The native building-stones, especially, have been compared with those from other states, and some of their excellencies have been brought out prominently, resulting in a great increase of the use of stone native to Minnesota.

10. In 1877 an examination was made of the water used for domestic purposes in the western part of the state. It had been discovered that very many of the common wells were foul, and that serious diseases that frequently terminated fatally were traceable to the use of the water in this condition. So general and wide-spread was this difficulty that serious alarm was felt by parties who were largely interested in the settlement and habitability of the prairies, particularly in the valley of the Red river of the North, lest the growing evil should render the country unfit for general agricultural occupancy. But the examination showed that the evil was due, not to any unhealthfulness

inherent in the water but to the general habit of using white pine planks for curbing in the wells. In the open air, the water of the prairies, which is naturally somewhat alkaline, confined in the impervious clay-reservoirs, such as nearly every well was, will act rapidly on any organic matter that comes in contact with it. The pitch of the pine was thus converted into organic acids, giving off sulphuretted hydrogen. Infusorial organic germs took up their abode in the foul waters, and the natural result of the use of such water inevitably followed. It was at once recommended that the use of wooden curbing be abandoned and that in its place some earthen, stone, brick or iron substance be used. This recommendation was widely published, both in Minnesota, and in the newspapers of Manitoba.

The consequence was a rapid decline of the evil. Many wells which had been abandoned were re-curbed with other materials. It was very soon known that pine well-curbing generated disease, and in a year or so nothing more, or very little, was heard further concerning the supposed foul waters of the western prairie portion of the state. The correction of this evil, and the removal of the suppressed alarm that was felt by some capitalists and by the health officers of the state, may be considered one of the most important visible benefits that have resulted from the survey.

11. At the same time the survey called attention to the possibility of obtaining artesian water at a moderate depth in the drift deposits over a wide tract of country in the northwestern part of the state, a circumstance that has latterly been widely improved with the most satisfactory results.

While these material benefits can easily be enumerated, those that are invisible cannot so readily be pointed out. Some good must result from a diffusion of knowledge concerning the geographical features of the state, and from the publication of accurate statements concerning its natural, undeveloped resources. There must be some benefit to the state in having its geology and natural history known. The scientific facts that are ascertained help to swell the data on which important conclusions are based, and to point out needed corrections in others that may have been published.

*Scientific results of the Survey.*

The additions to science that have sprung from the survey cannot be exactly enumerated. They are the common property of educators and scientists who may wish to make use of them.

Many facts have been published, the value of which cannot now be estimated, but they will go with other facts, some now known, and others to be learned, in Minnesota or elsewhere, to construct, by and by, general principles of interpretation of nature by which man becomes better and better acquainted with the laws and the circumstances that environ him, and with the great history of which he forms a part. Not in all cases have the conclusions, to which the published facts point, been stated, nor indeed have they been known. The principles deducible from a body of facts have to be the last fruits of an investigation, and in the case of a geological survey, while the indicated results may be foreshadowed by an examination of such incomplete data as the survey may afford from time to time, the final conclusions can be given only after the search for facts has been finished. Some such partial results have been published in the annual reports, and some important general truths have been announced in the final volumes (Vols. I. and II.) that have been issued.

In order, however, to indicate more definitely some of the scientific results of the work of the survey as they appear at present, the following enumeration is given, with references to the pages of the various reports in which the publication was made.

#### IN GEOLOGY.

1. Origin of kames, or "hogsbacks," supposed to be due to streams running on the ice and in gorges in the ice at the time of the glacial epoch, First Report, p. 62. This was first suggested in a report on Delaware county, Ohio [Geology of Ohio, Vol. II., p. 305] and a little later by N. O. Holtz, of the Geol. Sur. of Sweden [Geol. Fören. i Stockholm Forh. Band III., No. 3] and Warren Upham. [Geol. N. H., Vol. III., pp. 13 and 14.]

2. Origin of river-gravels and of "glacial lakes" on the open upland, and drift-covered prairies, First Report, p. 62.

3. Former existence of a lake of fresh water over the Red River valley, in northwestern part of the state. First Report, p. 63; Sixth, p. 31; named *lake Agassiz*, Eighth Report, p. 84; its approximate extent, Tenth Report, pp. 5, 141. [This lake was first suggested by D. D. Owen.\*]

\* Geology of Wisconsin, Iowa and Minnesota, p. 175, *et seq.* The suggestion of Owen was enlarged on by Henry Yule Hind, who added some definite data. Reports of progress; together with a preliminary and general report on the Assiniboine and Saskatchewan Exploring Expedition, made under instructions from the provincial secretary, Canada, by Henry Yule Hind. Presented to both Houses of Parliament by Her Majesty's command, August, 1860. London, 1860, pp. 178-181. Also, Narrative of the Canadian Red River Expedition of 1857, and of the Assiniboine and Saskatchewan Expedition of 1858. Two Vols., 1860, Vol., II., p. 230 *et seq.*



4. Suggestion of two glacial epochs in Minnesota. First Report, p. 61; Third, p. 185; Fourth, p. 62; Fifth, p. 36. [See also *Geology of Ohio*, Vol II., pp. 266-67, 303, 330.]
5. Separation of the Potsdam sandstone from the St. Croix sandstone. First Report, p. 68; Fifth, p. 29; Tenth, p. 123.
6. Probable non-existence of the Carboniferous rocks in Minnesota. Second Report, p. 76.
7. Separation of the "Lower Magnesian" into its two parts and the establishment of the sandstone member between them. The Jordan sandstone named, Second Report, p. 138; The St. Lawrence limestone named, Second Report, p. 152; defined, Fourth, p 32; Eighth, p. 103. The Shakopee limestone named, Second Report, p. 138; defined, Fourteenth, p. 325.
8. The decayed condition of the granites underneath the Cretaceous, in the Minnesota valley. Second Report, p. 163.
9. Establishment of latitude and longitude at various points in Minnesota through the aid of the U. S. Lake Survey. Fourth Report, p. 384.
10. The Cretaceous unconformable over the Cambrian at Mankato. Second Report, p. 178.
11. First fossils in the St. Peter sandstone. Fourth Report, p. 41.
12. Cause of the driftless area. Fifth Report, p. 36.
13. Approximate establishment of the date of the second, or last, glacial epoch, by the recession of the falls of St. Anthony. Fifth Report, p. 156; Final Report, Vol. II., p. 313.
14. The slates at Northern Pacific Junction the same formation as those at Little Falls. Sixth Report, p. 49.
15. Probable palæolithic man at Little Falls. Sixth Report, p. 53.
16. Definition of "Mesabi iron range" in Minnesota. Seventh Report, p. 21; Eleventh, p. 155; Thirteenth, pp. 24, 37.
17. Ten new species of fossils. Eighth Report, p. 60.
18. Three new species of fossils. Ninth Report, p. 115.
19. Position and extent of glacial moraines in Minnesota. Eighth Report, p. 72; Ninth, p. 182.
20. *Castoroides Ohioensis* at Minneapolis. Eighth Report, p. 181.
21. Unconformity between the Grand Portage slates [Ani-mike] and the talcose or sericitic schists [Keewatin] at Gunflint lake. Ninth Report, p. 82; Tenth Report, p. 88; Tenth, p. 132; Eleventh, p. 168; Sixteenth, pp. 69, 73, 67, 108, 239, 258, 268, 323, 357.

22. Extent of the moraines of the second glacial epoch in Minnesota and Iowa. Ninth Report, p. 298.
23. Titanic ore a constituent part of the gabbro. Tenth Report, p. 80; Fifteenth Report, p. 212.
24. The Labradorian Laurentian [the gabbro] extends, with some contemporary syenite, from Duluth to Little Saganaga lake and further eastward. Tenth Report, p. 98-101, 113.
25. The Quartz porphyry of the Great Palisades a part of the Cupriferos, and the equivalent of the "Red Rock," or red syenite associated with the gabbro. Ninth Report, pp. 36, 39, 58; Tenth, pp. 66, 75, 77, 99, 101, 110, 112; Thirteenth, p. 36.
26. Discovery of the Ogishke conglomerate. Tenth Report, p. 89.
27. The Animike the equivalent of the Taconic. Tenth Report, p. 132; Eleventh, p. 168; Thirteenth, p. 131.
28. Definition of the beaches of lake Agassiz. Eleventh Report, p. 141.
29. The Vermilion and Mesabi iron ranges visited and described. Ninth Report, pp. 103, 108; Eleventh, pp. 155, 168; Thirteenth Report, p. 20.
30. One new species of fossil. Twelfth Report, p. 8.
31. The iron ore of the Mesabi range in a different formation from that of the Vermilion range. Thirteenth Report, pp. 22 (fig. 5), 24, 37; Sixteenth, p. 79.
32. Three iron ore formations in Minnesota. Thirteenth Report, p. 24; Fifteenth, p. 212.
33. Paradoxides and Lingula (new species) in the red quartzite (so-called Huronian) at Pipestone. Thirteenth Report, p. 65.
34. The "upper Laurentian," or Norian, the equivalent of the gabbro, or "Mesabi range," of Minnesota. Thirteenth Report, pp. 127, 140.
35. The Taconic the equivalent of the Huronian. Thirteenth Report, p. 135; Sixteenth, p. 170.
36. Foraminifera of the Cretaceous in the boulder clays of Minnesota. Thirteenth Report, p. 164.
37. *Elephas primigenius* in Winona county. Thirteenth Report, p. 147.
38. Thirty-nine new fossil species. Fourteenth Report, p. 57.
39. One new family of fossils. Fourteenth Report, p. 104.
40. One new genus of fossils. Fourteenth Report, p. 83.
41. Three new genera of fossils. Fourteenth Report, p. 107.
42. Four new species of fossils. Fourteenth Report, p. 313.

43. The Vermilion group, or crystalline schists named. Fifteenth Report, p. 4; conformable with the Laurentian gneiss, Fifteenth Report, pp. 127, 178, 296; Sixteenth, p. 335; Seventeenth, p. 32.

The jaspilyte embraced in basic eruptive rock now converted to chlorite schists. Fifteenth Report, pp. 221, 269, 319, 326; Seventeenth Report, pp. 37-42, 123.

44. Mica schist derived from hornblende schist. Fifteenth Report, pp. 338, 357; Seventeenth, p. 32.

45. Derivation of gneiss *in situ* from fragmental rock. Fifteenth Report, pp. 353, 361, 368; Sixteenth, pp. 69, 81, 104, 107.

46. Three new species of fossils. Fifteenth Report, p. 478.

47. Stratigraphic position of the Animike. Fifteenth Report, p. 356; Sixteenth, pp. 79, 81, 87, 108.

48. A driftless area in N. E. Minnesota. Fifteenth Report, p. 350.

49. Potsdam (or primordial) quartzite of S. W. Minnesota the equivalent of the upper quartzite of the Huronian in Canada. Sixteenth Report, p. 22.

50. Gabbro and felsyte in the area of the original Huronian. Sixteenth Report, pp. 29, 27.

51. The Animike the equivalent of the Huronian. Sixteenth Report, pp. 38, 352.

52. The upper Huronian (or Potsdam) quartzite unconformable over the iron ore formation at Negaunee, Mich. Sixteenth Report, p. 44; and at Ishpeming, Sixteenth Report, p. 46; and at Bessemer, Sixteenth Report, p. 55.

53. The Gogebic iron ore on the horizon of the Animike of Minnesota. Sixteenth Report, p. 59.

54. The "Laurentian" overlies the Gogebic strata at Ironwood, Mich. Sixteenth Report, p. 58.

55. The Keewatin schists conformable with the Vermilion mica schists. Sixteenth Report, pp. 76, 350; Seventeenth, p. 37.

56. The Vermilion sediments largely of eruptive origin, but principally distributed by sedimentation. Sixteenth Report, p. 77.

57. The Animike becomes nearly vertical, and embraces a part of the great Ogishke conglomerate. Sixteenth Report, pp. 91, 98.

58. "Laurentian" gneiss overlying Keewatin strata. Sixteenth Report, p. 104.

59. The Vermilion ore not Huronian. Sixteenth Report, p. 175.

60. Two unconformable slate formations in the Marquette region. Sixteenth Report, pp. 178, 359; Seventeenth, p. 43.

61. Conglomerate in Laurentian gneiss. Sixteenth Report, pp. 219, 293, 298, 334.

62. The jaspilyte not of eruptive origin but arranged by sedimentary deposition. Fifteenth Report, pp. 223-247.

63. Suggestion that the crystalline schists (Vermilion series) may be due to hydro-thermal action at deep levels, on the volcanic tuffs, stratified by sedimentary action, of the age of the Keewatin, and may occur at different levels in the Keewatin strata. Seventeenth Report, p. 36.

64. Demonstration by the deep well at Stillwater, that the Kewenawan rocks are not of Mesozoic age. Bulletin No. 5, p. 26.

65. The gabbro outflow, of the age of the Pewabic [Potsdam?] quartzite. Sixteenth Report, p. 88; Bulletin No. 5, p. 34. (Section of the Duluth deep well.)

66. Microscopic description of the peridotites, gabbros, diabases and andesytes of the state. Bulletin No. 2.

#### IN ZOOLOGY.

1. Twenty-seven species of mammals named from the vicinity of Big Stone lake, one variety new. Thirteenth Report.

2. Two hundred eighty-one species of birds credited to the state. Ninth Report.

3. One hundred species of aphids credited to the state, forty-two of which are new to science. Fourteenth Report and Bulletin No. 4.

4. Eighty-one species of Crustaceans credited to the state, of which twenty-seven are new to science. Fifth, Seventh, Tenth, and Twelfth Reports.

5. Eighty-seven species of mollusks are credited to the state. Fourteenth and Sixteenth Reports.

6. Eighty-nine species of mollusks are reported from Winona county. Sixteenth Report.

#### IN BOTANY.

1. Fungi in Minnesota, 558 species identified. Fifth Report. [Published simultaneously in the Bulletins of the Minnesota Academy of Sciences.]

2. Other plants identified in Minnesota, 2107. Twelfth Report and Bulletin No. 3.

3. Thirteen species and four varieties of plants new to science. Twelfth Report and Bulletin No. 4.

4. Definition of the forested area of the state, and of the latitude limits of some of the trees. Twelfth Report.

#### THE FUTURE WORK OF THE SURVEY.

Besides the foregoing results, there are important scientific memoirs and reports that await publication. These form two further final volumes, and were offered for publication at the last meeting of the State Legislature. One contains the final reports on Birds and on Mammals, and the other is mainly palæontological. The palæontological volume will be No. 3 of the final volumes.

The unfinished work of the geological survey proper lies in the northern portion of the state, embracing the crystalline rocks and the various questions of economic and technical geology that pertain to them. This is the most important, as it is the most difficult and costly, of all the work yet done by the survey. A large amount of this kind of work has been done. It remains to thoroughly examine the specimens collected, give their relations, construct the geological maps and to publish the results.

And when this survey is finished, it can be considered only a commencement of the research that will yet be conducted on the geology of the state. It is an effort to put into systematic relationships some of the obvious facts that can easiest and quickest be gathered up by a geological observer. So far as it goes it is useful, and is absolutely necessary to the future geologist who would inquire further into these relationships. It will furnish for him a broad stepping-stone from which he may examine more minutely many things that now have to be passed over unstudied, just as the survey of D. D. Owen has furnished for us an earlier classification from which to take departure in all our examinations.