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CONTAINING AN ACCOUNT OF THE ANNUAL MEETING

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BY
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LETTER OF TRANSMITTAL

TO HONORABLE A. T. BLISS, *Governor of the State of Michigan:*

SIR:—I have the honor to submit herewith the Fifth Annual Report of the Michigan Academy of Science, for publication in accordance with Section 14 of Act No. 44, of the Public Acts of the Legislature of 1899.

Respectfully,
JAS. B. POLLOCK.

Ann Arbor, Mich., December 1, 1904.

THE TOPOGRAPHIC SURVEY OF MICHIGAN.*

BY ISRAEL C. RUSSELL, PRESIDENT OF THE MICHIGAN ACADEMY OP SCIENCE FOR 1902-1903.

The excellence of the maps a nation or a state produces of its own territory is an index of its rank in the scale of civilization. The absence of such maps in the case of nations or states not too young to have had time for extensive internal improvement, is equally symbolical of lack of energy and of retarded intellectual and commercial growth.

The more enlightened nations of Europe at the present time are in advance of all other governments in the completeness and accuracy with which their respective domains have been surveyed and mapped. Germany, France and England, in particular, among the larger land owners of the Old World, possess excellent maps of the regions within their respective boundaries. The nations referred to have not only surveyed their possessions once, but in several conspicuous instances, no sooner was a map of a given degree of excellence and an advance on all previous attempts in the same direction, obtained, than still more accurate surveys and still larger-scale maps have been demanded for military and industrial purposes, arid re-surveys, and the production of still more exact and more detailed maps undertaken. This earnest and constantly increasing desire manifested by the nations of Europe, for accurate information concerning the lands within their immediate borders, has also in many instances, but most conspicuously in the case of the English in India, been extended to their insular possessions. While admirable maps are available of nearly all the countries of Europe, similar maps embracing any considerable areas in America were almost unknown up to the time of the organization of the United States Geological Survey in 1879. Even at the present time creditable maps of the entire area of only four individual states can be had, and in Michigan less topographic work has been done than in any other state, with the exception of Florida and Minnesota. There are maps and maps, however, and in planning a survey of a state it is necessary to decide as to what kinds of maps are needed and to reckon cost.

*Revised December, 1904.

WHAT IS A MAP?

The maps we most usually see, in atlases, on the walls of schoolrooms, in works of travel and histories, etc., are representations on a plane surface of political boundaries, the positions of towns, and the outlines of such natural features as the shores of oceans and lakes, the generalized courses of streams, etc. The positions of these objects are indicated with more or less accuracy by means of two co-ordinates, namely latitude and longitude. The various methods of representing portions or the whole of the curved surface of the earth on a plane, or of projection, need not be considered at this time. The characteristic feature of the maps referred to, is that by means of but two co-ordinates, only the relative horizontal positions of objects can be represented and not relief of surface. Such maps are mere diagrams in two dimensions, and take no account of the heights and shapes of mountains, the breadths and depths of valleys, etc., or, in short, of any element of the earth's surface rising above or depressed below an assumed plane. They are not only devoid of expression, but to a great extent meaningless and even misleading. When the pupil steps outside the schoolroom he finds the region about him not a featureless plain, as his maps have taught him, but diversified in relief in many ways.

The maps of Europe and the more modern maps published in America, to which reference has been made, in addition to representing the relative positions of objects on the earth's surface, indicate with an equal degree of accuracy the heights and shapes of mountains and hills, the forms of valleys and the slopes of their enclosing uplands. In many instances, the shapes of lake basins below the water's surface and of the ocean's bottom are also quantitatively shown. In brief, such maps represent portions of the earth's surface in three dimensions, by means of three co-ordinates, namely, latitude, longitude and height above or depth below sea level.

While *map* is a word generic in its significance and used to include many species, as they may be termed, the particular species, to which attention is here invited, is the one on which relief of the surface is represented, or the topographic map. On topographic maps there are also presented in most instances, all of the data that can be shown on a diagram, as, for example, political boundaries, roads, shore-lines, etc., or the relative geographic positions of objects when reduced to a horizontal plane. The significance of the word *topographic* in the above connection is principally in reference to relief of surface. The term has also acquired, by common consent, another significance, namely accuracy. Maps on which attempts are made to show relief, are usually of such a degree of excellence that accuracy in their construction has become a chief reason for their existence.

The demand for precision in the surveys on which topographic maps are based, has become so rigid and the degree of skill required to present it in final dress so great, that topographic mapping has developed into a distinct branch of applied science, differing from other methods of surveying.

The successful topographer is not only a surveyor but to no small extent an artist. In his finished work, if well done, there exists, side by side, nay in the same line, the accuracy of the geodesist and the expression of the landscape painter. A topographic map is a picture of a given surface in which every part is precisely located in reference to three coordinates. It is a representation, we will say, of a mountain from every direction in which it may be seen. From such a map not only is a bird's-eye view attainable of the region delineated, but from it one can read distances, heights, depressions, and the slopes or gradients of the surfaces of uplands and valleys. Nor is all told that may be read on such a map, when the bare representation of the existing land surface is interpreted. With an accurate topographic map of an extensive region, such as a mountain range, or a river system, in hand, the geographer is enabled to read between the lines, as it were, much of the geographic history of the area represented and to predict with a high degree of confidence the changes that are to come. In skilled hands, an accurate topographic map becomes an instrument of research, and one that is indispensable to those who seek to learn the laws governing our physical environment.

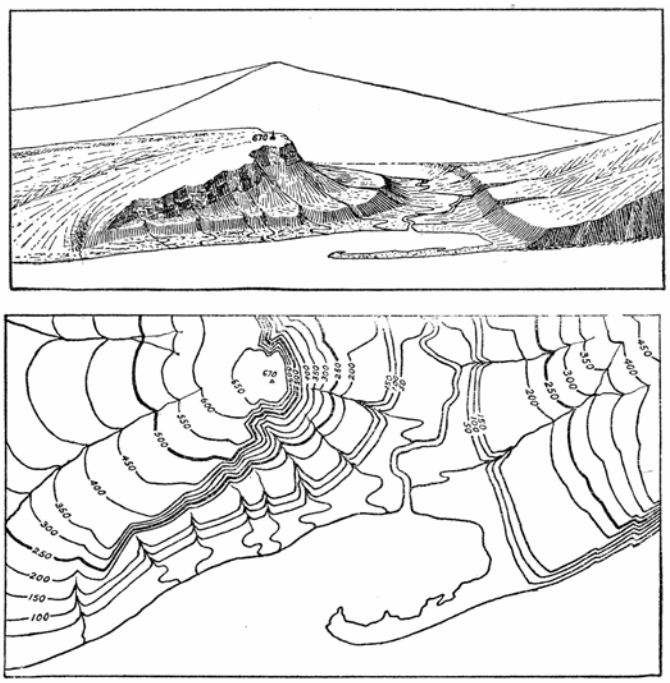
CONTOUR TOPOGRAPHIC MAPS.

In searching for methods by means of which the relief of any region may be represented on a plane surface, resort has been made to various devices, such as brush shading, shading by means of short inclined lines or *hachures*, continuous lines drawn through points having the same elevation or *contours*, etc. Of these various methods, the last mentioned, namely, the use of contour lines, has by long experience and especially when the question of expense is considered, been found the most satisfactory by the majority of geographers. The contour topographic map is without question the map of the future.

By means of lines drawn through all points represented on a map, having the same elevation or the same depression in reference to the assumed datum plane, the shape of the surface in question may be accuratly portrayed. Such lines are termed contours, and a map on which relief is shown by this method, becomes a contour topographic map. Contour lines are few or many, according to the horizontal scale of a map, and the degree of completeness with which it is practicable to indicate the relief of the surface represented. The vertical distance between two adjacent contour lines, or the contour interval, may be any measure, as for example, ten, or one hundred feet. By this method not only can the elevation of any point included on a map which is crossed by a contour line, be read at a glance, but the elevation of any point between two adjacent lines may be judged with a close approximation to accuracy.

In order to make the significance of contour lines more clearly understood, a picture is here presented through the courtesy of the U. S. Geological Survey, of a bit of coast, with a terraced valley between two hills on the adjacent land; and beneath it is a contour map of the same locality, on which the contour interval is 50 feet.

If one imagines the land shown in the sketch, to be intersected by several horizontal planes, fifty feet apart, the lines produced by the intersection of such planes with the surface of the land, would' be contour lines. These lines, if viewed in all parts from directly above, would show the shape of the surface of the land. From the illustration it will be seen that a contour map is a horizontal projection of contour lines; that is, each contour line is dropped, as it were, to the plane in which the lowest in the series is situated, which is usually the horizon of the ocean's surface, and the figures placed upon it show the height of its previous position.



Ideal Sketch and Corresponding Contour Map.

By comparing the above sketch with the map of the region it represents, it will be seen that where slopes are steep, the contour lines are near together, and where the slopes are gentle the lines are wider apart; the vertical distance between any two adjacent contours being always the same. In making surveys for contour maps, actual lines are not marked on the land, but the topographer locates on his field sheet a number of points having the same elevation, and while occupying these stations, sketches the course of the lines connecting them. It is to the accuracy of this freehand sketching controlled by a number of definitely located points, that the expression and much of the value of the finished map is due.

It is by means of contour topographic maps of the nature just described, usually drawn to a horizontal scale of about one mile to one inch, or $^{1}/_{62500}$ of nature, but frequently of still larger scale, that most enlightened nations, as previously stated, are striving to represent their respective territories. No doubt the reader will enquire: Why the widespread demand for such maps among the people of the most progressive countries?

USES OF CONTOUR TOPOGRAPHIC MAPS.

The advantages of contour topographic maps over the more familiar diagrams of boundaries, roads, streams, etc., are due to the fact, as already stated, that they are representations of a given area in three instead of two dimensions. From them vertical as well as horizontal distances can be measured. The value of the vertical element or the relief, is very great, especially when combined as it is on all creditable contour maps, with the results of accurate linear surveys.

To attempt to explain all the aids to industrial, commercial and intellectual development, furnished by contour topographic maps, would require more space than I have at command; and besides, on account of their faithfulness to nature, such maps create for themselves new and previous to their appearance, unsuggested uses. In many branches of nature study, they may be likened to the application of a previously unemployed agency, such as the use of steam, electricity and compressed air in the mechanical arts. In the hands of engineers, geologists, foresters, biologists, farmers, statesmen, and to teachers and students in many branches of knowledge they offer not only direct aid, but suggest new methods and untrodden paths of research.

To Engineers: Contour topographic maps supply such data to engineers as is obtained frequently at great expense, by means of preliminary surveys, such, for example, as are usually made for the trial location of railroads, canals, irrigation systems, reservoir sites, aqueducts, etc.: or in brief, for all engineering works in connection with which the relief of the surface of the earth throughout a considerable and frequently great extent of country needs to be known before the best locations for the far more expensive detailed surveys can be chosen.

In reference to the direct money value to engineers, and to the companies, corporations, etc., employing them, of a contour topographic map of Michigan, for example, it may be shown that with such a map in hand, a railroad could be projected across the State, grades computed, cuts and fills measured and approximate cost of construction ascertained without expense for trial surveys. More than this, not only could one such line be studied but all possible routes between any two localities within the State, discovered and scrutinized and from a comparison of them the most desirable location chosen, for both engineering and commercial reasons. All of this can be done with the aid of a creditable contour topographic map, without the expenditure of a single dollar for surveys. What has just been stated is equally true of ship and drainage canals, trolley lines, telegraph and telephone lines, water supply and sewer systems, or, in short, all geographically extended undertakings that states, municipalities, companies, etc., commonly engage in.

In what has just been stated, reference is made to savings that may be secured by using a topographic map in place of preliminary surveys, but as may be illustrated by many definite examples, contour topographic maps are of service in suggesting ways in which railroads, etc., already constructed or for which final, detailed surveys have been made, can be shortened or otherwise improved.

In proof of the above, perhaps seemingly too sanguine assertions, a few from many specific examples that are available may be of interest:

In the summer of 1901, the Wabash Railroad Company was locating a railroad line from the Ohio river across Jefferson and Harrison counties, Ohio, to connect with the Wheeling and Lake Erie railroad; and during the same summer a contour topographic map of the region referred to was being constructed by the United States Geological Survey. The railroad surveys were completed, a location chosen, grades, cuts, etc., including a tunnel, decided on, and contracts for construction entered into; when advance copies of the topographic map that was being made came to hand. From an inspection of the map the possibility of a shorter route, with equally favorable grades, and without the necessity of a tunnel, was discovered. The new location was at once adopted, and resulted in the saving of $80,000.00 in construction. This correction of a detailed railroad survey, with the aid of a contour topographic map, was made possible by a study of the map itself, and without expense.

Again, at Waterbury, Connecticut, after two sources of water supply for the city had been surveyed at an expense of $10,000.00, a contour topographic map of the region about the city, made by the United States Geological Survey, was received by the engineer in charge, Mr. R. A. Cairns, and from an inspection of it, a better source from which to obtain water was discovered, and finally adopted. Not only was the new site and the one now supplying the city of Waterbury, suggested by the study of the map referred to, but not one cent was expended for preliminary surveys.

Much additional testimony in the above connection might be presented, but a single example must suffice:

The Chief Engineer, L. A. Hyer, of the Washington and Chesapeake Railway Company, in a letter expressing his appreciation of the topographic work done by the United States Geographical Survey, says:

"I used your contour maps in the location of this road. Had to rerun but very little of the line and reduced the number of curves to six from 107, or saving in all 3,266° of curvature, shortening the line 4.7 miles over a line previously located by me without the aid of these maps."

In a memorial advocating a topographic survey of Michigan, presented to the Legislature in 1897, by the Michigan Engineering Society, the reasons for demanding such a survey are tersely stated and I cannot do better than to quote them in part, in proof of the value of topographic maps to engineers:

“No topographic map of the State of Michigan, and, in fact, no map of the State worthy of the name, now exists or can be compiled from existing surveys.

"Such a map cannot be constructed except as the result of an accurate topographic survey.

"Much money is wasted every year in re-surveys owing to the lack of a general compilation of past surveys in a convenient map.

"The increase and extension of systems of land drainage and irrigation imperatively demand a contour topographic map by which alone they can be planned in a systematic and efficient manner.

"The construction of systems of sewerage for our growing towns would be greatly aided by topographic maps.

"Topographic maps are an absolute necessity before intelligent judgment can be given between various projects of water supply for towns, and for this use alone they might well be worth all that they would cost.

"They are a prerequisite for the scientific study of our water powers, and of those areas which should be preserved for forest culture at the head waters of our streams in order to prevent the depletion of these water powers.

"They would' aid immensely in securing the best locations for railroads, both steam and particularly the electric roads which will eventually gridiron the State, and would save large sums of money which would otherwise be spent for preliminary surveys or useless construction, the interest on which the people of Michigan would have to pay.

'They would be of great value to both the sellers and purchasers of land by showing the character of the surface, whether level or hilly, wet or dry, timbered or cleared, well or poorly watered.

"The establishment of a true meridian line in every county, which is part of the proposed work, would go far toward diminishing the litigation which arises out of erroneous surveys due to variation of the magnetic needle; and the establishment of permanent bench marks in every township, referred to a common datum, would be of great value to land owners in planning extensive systems of drainage."

To Geologists: I make bold to say, and without fear of challenge from competent judges, that a high grade topographic map, on such a scale as the nature of the region studied may dictate, is indispensable for accurate geologic work, and for the adequate presentation of the results of geologic surveys. To sustain this statement I might present detailed statistics of the large sums that have been applied from appropriations for geologic surveys, for purely topographic work, both in European counties, and by our Federal and some of our State geologic surveys. Several states, however, including Michigan, have ignored the fact that topographic should precede geologic surveys, or have been unable to bear the expense of preparing topographic maps for the use of their geologists, but, instead, have required them to do what they could without maps, or piece together such diagram-maps as were available. In all such instances the best geologic work that could be done was in large part provisional, and in most cases re-surveys became imperative. By this illogical method the preparation of final reports has been long delayed, and much valuable time and large sums of money wasted.

The urgent demand of a topographic survey of Michigan in aid of the geologic survey that has been in progress with various interruptions since 1837, is well expressed in the following extract from a letter by L. L. Hubbard, State Geologist, under date of May 20, 1895:

"It gives me great pleasure to express my appreciation of the efforts made by the Michigan Academy of Science to procure the enactment of legislation to authorize the construction of a topographic map of the State. The absence of such a map is a constant regret to the members of the Geological Survey, not only in their office work, but particularly in the field. We now have to use copies of township plats made fifty years ago, when apparently no great effort was made, or, under the conditions then existing, could be made to delineate the topography with any approach to detail. To improve these maps and to locate our specimens we often have to meander roads at a great loss of time, and we never can be certain of the accuracy of our barometrical observations, which in themselves take much time unless, we employ an extra man to make simultaneous observations at some point of known altitude. You can appreciate the difficulty of correlating beds that outcrop at different horizons, when the difference of altitude is unknown.

"Indeed, if we had a good topographic map, I am sure we could save a great deal of money and do more work in a given time than we do now. We should also know much better where our work could be done to the greatest advantage."

To Foresters: In the forest culture of Germany and other European countries, topographic maps are in constant use. The setting aside of great forest reserves in the United States was followed immediately by the preparation of topographic maps of their several areas as an initial step to the study of forest conditions, the prevention of forest fires, and the ultimate harvesting of a forest crop. The necessity is thus indicated for accurate topographic maps in the scientific study of the forests of Michigan recently begun, and which promises such great returns, especially in the way of re-foresting our depleted pine-lands.

In reference to the value to our forestry survey, and through it to every person living in Michigan, of a topographic map of the State, in order to regain in part our squandered inheritance, I am permitted to quote the following statements by C. A. Davis, Instructor in Forestry in the University of Michigan, who has made a premilinary study of the forest reserves of the State:

"A topographic survey and resulting map, of Michigan, is of fundamental importance and a necessary preliminary step, if we are to have intelligent and well planned forestry work done in the State.

"The maps now in existence, even those of long settled parts of the State, are, with the exception of those of comparatively small areas recently produced by the United States Geological Survey," very inaccurate, give no indications of the surface conditions, and none of "the data demanded for even the intelligent location of a farm, and to the forester, are of no use except for the most superficial study of the complex problems with which he has to deal. These facts have been borne in upon me in my own efforts at field-work in forestry, and have caused me great annoyance and waste of time, for in each area studied I have had to construct a map as I proceeded with my work, at great expense of time and at no small cost. The contrast of having a well prepared topographic map was impressed upon my mind when the advance reproductions of the topographic map of the quadrangle including Ann Arbor, became available for use. With these in hand it is possible to do at least four times the work per day as formerly, for the reason that the details of the topography can be read from them at a glance and notes upon soil distribution, vegetation, etc., can be indicated on them with great exactness and very rapidly.

"Should the topographic survey of Michigan, recently begun, be extended over the entire State, as eventually it must be, the work of arriving at a final solution of the forestry problems, now unnecessarily complicated, owing to the absence of a reliable topographic map, would be greatly simplified."

To Biologists: Nearly every civilized country in the world has published the results of systematic examinations of the plants and animals within its boundaries. Such a biologic survey, or study of both the flora and fauna of the United States, is now being actively conducted by the Department of Agriculture at Washington, and either in affiliation with that department or working independently, several of the states of the Union are carrying on similar surveys, or have done so in the past. The immediate economic aim of national and state biologic surveys, is to learn how plants and animals may be made more useful to man; to ascertain which are our friends and which our enemies among the living hosts surrounding us; to discover the fungi, parasites, bacteria, bacilli, germs, or by whatever name the unseen legions may be designated, which cause blights among plants and disease and death of the lower animals and of man. The pioneer work in this great field has been done, but the true biologic study is still in its infancy. As an example of what may be accomplished by such surveys, reference need only be made to the work of Major Reed in banishing yellow fever from Cuba. Similar beneficial results have been reached in other directions, and many more safeguards to life and means of advancing the material welfare of man, it may be stated with entire confidence, will be discovered in the future.

In the study of the vast and but partially explored domain of life, one of the first steps is to make a concise record of carefully observed facts. All life, it is safe to say, is molded and controlled by its environment. The mountains are clothed with plants in orderly ranks from their bases up to the lower limit of perpetual snow, and even above that limit lives the blood-red *Protococcus*. In each zone of plant life there are certain animals peculiar to it, and these again, in many instances, are hosts for other plants and animals. This definite distribution of living forms in reference to differences in elevation, in exposure to light, in range of temperature, in humidity and still other conditions, applies to hillsides as well as mountain slopes. It is modified, too, by differences in latitude, and is dependent in a conspicuous way on position with reference to seas, lakes, and streams. In brief, a biologic survey is concerned primarily with the distribution of plants and animals. Commonly such distribution is termed geographic, but from what has just been stated, it is evidently topographic as well. In the ideal biologic survey, the distribution of each species of plant and animal with reference to both geographic position and elevation, needs to be accurately known. To record such data, and discover the causes which control distribution, or, in other words, to learn the conditions on which life depends, and hence be able to modify it or strive to exterminate noxious forms, an accurate map showing the relief of the country studied, the distribution of water bodies, the inclination of land surface, etc., is a primary requisite. Without such a map a critical biologic survey of any extensive region is impossible. Delay in making such surveys means continued exposure to unseen enemies, and neglect of opportunities to utilize benign agencies which are at our command.

A biologic survey of Michigan was embraced in the plans of Douglass Houghton, in 1837, for the study of the resources of the State, but not carried into effect. Up to the present day no adequate study of the native plants and animals of Michigan, or of the species introduced and their influence, whether harmful or beneficial, has been made. This matter is now commanding attention, and the first step in the desired direction, as all biologists will agree, is the preparation of an accurate topographic map of our broad domain.

One phase of biologic study relates to the diseases of men. In Michigan this subject is now in part, entrusted to the State Board of Health. Among the aims of that organization is the discovery of the ways in which contagious diseases are disseminated, the influences of drainage on health, the dangers resulting from the pollution of streams, the geographic distribution of diseases, etc. In these and other related subjects pertaining to medicine and hygiene, a knowledge of geographic conditions is plainly of fundamental importance. This necessary preliminary information, however, cannot be had by the guardians of health in Michigan, until a topographic map of the State is available. With such a map in hand, the facts now known concerning the relation of diseases to environment could be clearly shown, and much aid afforded in the search for still hidden causes of bodily ailments.

To Farmers: The possibilities of agriculture are determined mainly by soil and climatic conditions. The better these are known and the better this knowledge is applied, the more successful the results. To furnish this knowledge, the Agricultural Department in Washington issues thick volumes filled with the results of soil survey, and accompanied by portfolios of maps on which soil conditions are indicated; and the United States Weather Bureau each year, each month and each day, sends out maps on which climatic and weather conditions are graphically recorded. Both in the gathering of these important data and in their distribution maps are essential, and the better the maps, the better will be the results. In the study of soil conditions more definitely perhaps than in related branches of research, is the influence of relief and, depending on the relief, of drainage and distribution of soil-moisture, to be taken into account. The high aim entertained in this connection by both students of agriculture and scientific agriculturists, however, can never be attained without the assistance of accurate topographic maps in planning investigations and exhibiting results.

The ice sheets which once completely covered Michigan, on retreating left an irregular surface. In places the ground is high, well drained and admirably adapted to various kinds of farming. Large areas, however, as in Saginaw valley, and many other sections of the State, are low and swampy. The drainage of these areas is in progress, but the task has scarcely more than been begun. One of the great benefits of a topographic map would be to show how these now useless areas may be reclaimed and converted into agricultural land, as has been done in the case of some of our celery and truck farms, or the marl and peat they contain utilized for making Portland cement, and for fuel.

Our rural communities are interested in and will, without doubt, reap priceless advantages from improved roads, free mail delivery, segregation of schools, etc. In all of these directions, an accurate knowledge of the geography of the State is necessary for those who control legislation, and devise far-reaching plans for lessening the burdens of isolated communities.

To Statesmen: The business affairs of the State of Michigan are intrusted to a governor, legislators and other officers. The duties imposed upon these representatives of the people necessitate an extensive knowledge of the geography of the State, in order that they may intelligently carry out the laws already enacted, and judge wisely as to the merits of the countless and exceedingly diverse measures of public concern which arise. At each session of the legislature numerous franchises, charters, etc., are asked for, pertaining to the building of railroads, trolley lines, telegraph and telephone lines, municipal improvements, enlargement of cities, incorporation of towns, location of factories, etc., each of which demands a critical and frequently extensive knowledge of geographic conditions in order that the full import of the proposed enterprises may be understood and the vested rights of parties not directly participating therein, properly guarded.

In several memorials that have been published, relating to the topographic survey of Massachusetts, New York, and other states, much stress is placed on the value of topographic maps in relation to taxation and the sale of land. These needs are not so urgent in Michigan as in several of the older states, for the reason that in this State surveys for the parceling and sale of land have already been made. The maps resulting from these surveys, however, are of but little value in showing the character of the land, and hence are inadequate as a basis for equalizing assessments.

The usefulness of topographic maps to legislators, is also apparent from the facts already mentioned in reference to special surveys that are being carried on at State expense, in order that they may judge intelligently as to the needs of such undertakings and of the efficiency with which they are conducted.

Such a survey as is under consideration, furnishes the best of base maps for the graphic representation of facts relating to distribution of population, industries, products or other statistical information, for which there is a constant demand by statesmen, newspaper editors, and, in fact, by all the more enlightened citizens of a republic.

To Students and Teachers: Aside from all direct money returns and money savings which a topographic map insures, such a map of a state is of incalculable value to its children whether of tender or mature years. The conspicuous advances recently made in the development of physical geography has opened an almost boundless region of fascinating study which brings the student in direct communication with nature. One of the greatest attractions of what has justly been termed the new geography, is the recognition of the fact that the earth is not a finished work, but the molding and sculpturing, and even the coloring and decoration of its surface are still in progress. One of the great tasks of the geographer is to discover how the many features of the land, such as mountains, valleys, canyons, fruitful vales and upland pastures, came into existence. The key to the situation was discovered when the "everlasting hills" were found to be transient forms, and terra firma never at rest. The upheaval of land above the sea and its sculpturing into diverse forms with marvelously intricate details, was begun in the remote past, is still in progress and, so far as can be judged, will continue into the distant future. To understand what changes the earth's surface has undergone, and predict although with reserve, what mutations are to follow, the geographer studies the changes now in progress and from them seeks to discover wide-reaching laws.

Those who question nature and listen for her answers, go forth into the fields, follow the streams, traverse the pathless forest or stand alone on the silent and awe-inspiring mountains. To view natural processes at work in shaping and re-shaping the earth's surface is one of the greatest charms of such excursions. Travelers who have wandered farther in this quest than those who sought the Holy Grail, have returned to the vale in which they passed their youthful days, only to find that much for which they looked could there have been seen while they were yet young had they been taught to see, or rather to observe. The sculpturing of the most magnificent mountain, is reproduced in minature in many a hill; the essential features of the most profound canyon have their counterpart in the trench cut by the wayside rill. The tools with which nature works are in each case the same, it is only the size of the blocks that are being sculptured and the rate at which the task is being carried on, that differ. For these and kindred reasons it may be shown that the study of geography should begin at home.

To understand the work of even a moderate sized river, however, and to learn how, in one part of its course, erosion and canyon cutting are in progress, and how debris is being taken into suspension, and carried to where it can be spread out in flood plains, alluvial cones, deltas, etc., making new and richer lands, can not be fully shown and quantitative measures made, rate of degradation or upbuilding, etc., ascertained, without the aid of accurate maps. But few people can retain in mind the relations of the various details to be observed in the relief of even a square mile of a moderately rough portion of the earth's surface. The task of visualizing or of picturing before the mind's eye the relief and interrelations of the surface features of a county or a state, surpasses the ability of even the best trained geographer, without the aid of maps which reproduce these features in miniature. The aim of these truisms is simply to show that a map, and especially a contour topographic map, drawn accurately with reference to both horizontal and vertical distances, is the chief tool with which the geographer carries on his researches, and affords the best means of presenting his results.

The beginner in geography should study a restricted region with the aid of a good map, and also study the map with the aid of an accurate knowledge of the area it represents. In this way, as in no other, is the eye and the mind trained to interpret natures picture-writings, and at the same time acquire skill in reading the draftsman's representations of them. While the interpretation of nature is the chief aim in such field studies, an essential means to that end is the ability to read topographic maps. In this connection, it is not requiring too much when teachers are asked to instruct their pupils in the art of reading topographic maps as well as the printed page. This can be done to the greatest advantage by means of local or home maps.

One of the most important principles in the teaching of the new geography, is that geographical studies should begin at home, and widen in constantly enlarging circles until, as an ultimate aim, the meaning of the surface features of the entire earth is grasped. As has been said by one of our leading teachers of geography: Inattention to home surroundings during school years may be followed by geographic blindness throughout life.

The tens of thousands of boys and girls in the schools of Michigan cannot make a proper beginning in geography until a topographic map of the land surface with which they are individually familiar, is available for their use. The study of a topographic map of the region about every school should be required of each of its inmates. In each schoolhouse, accurate topographic maps of the town, county and state in which it is situated, should have precedence over all other maps. These important aids to education can be had in Michigan at an expense of a very few cents, when once a topographic map of the State, such as has just been begun, is available.

While the important economic uses of topographic maps make but little appeal to me personally, except in a general way, as a citizen of a great and prosperous State, the educational value of such maps does come home to me with perhaps undue force. With an accurate map of Michigan available, my task of imparting to my classes in the University a knowledge of the broader principles of geology and geography, would be greatly lessened. In urging an early completion of the topographic map of this State, I am confident I have the hearty support of every teacher in it.

Much might be said in reference to the multiple advantages to be reaped from such a survey and map as is here advocated, did space permit, but other aspects of the work demand attention. Before turning to another phase of this discussion, however, I wish to direct attention to one other fact,—although such a course seems unnecessary, so plain is the conclusion referred to, but it is this: once a topographic map of Michigan is made, it will descend as a rich legacy to all future generations of engineers, geologists, farmers, manufacturers, teachers, students, legislators, etc., of our growing State, and its influence for good on intellectual, industrial and commercial development be far-reaching and cumulative.

THE TOPOGRAPHIC SURVEY OF THE UNITED STATES.

At the beginning of the work of the United States Geological Survey, in 1879, there was no map available of the region to be studied, which would serve as a basis for the geologic map ordered by Congress. To meet this difficulty, a topographic division of the survey was promptly organized, and slowly drilled until it became fully as efficient as any other similar corps in the world. During the past twenty-three years, the arduous task of making a contour topographic map of the United States has been carried steadily forward, and greater and greater excellence in the finished maps secured, as a result of increasing experience and more and more exacting demands. The maps produced during the past decade are worthy of critical comparison with the best maps of like character on the same scale, and produced at similar cost, made anywhere in the world.

The plan adopted by the United States Geological Survey in mapping our country, is to divide it into quadrangles, representing what is termed one square degree. That is, the standard sheets include one degree of latitude and one of longitude. The area shown on each sheet varies in accord with its geographic position, but in general embraces about 900 square miles. These maps are drawn to scale of about two miles to one linear inch, or $^{1}/_{125000}$ of nature, and relief is shown by contour lines, with intervals ranging from 100 to 20 feet, according to the roughness of the land. When circumstances render a larger scale desirable, however, the quadrangle is made to include one-quarter of a square degree, and the scale is enlarged to one mile to one inch, with contour intervals of 20 feet, or less. Special maps are also made on still larger scale for mining, municipal and other purposes. On these maps the lakes, streams, etc., or the hydrography, are represented in blue; the contour lines in brown, and the cities, roads, houses, etc., or what is termed "culture," in black; the lettering is also in black.

Contour topographic maps of the character briefly described above, have been made by the United States Geological Survey when the demand for them as base maps for geologic work was greatest. The maps now available embrace a portion of every state and territory in the Union, and although to a great extent the published sheets are disconnected and independent, each one has its allotted place in the contemplated map. Up to the present time about one-third of the area of the United States has been surveyed, and for the completion of the task at the rate it has been progressing during the past decade, at least fifty years will be required.

CO-OPERATION BETWEEN THE FEDERAL AND STATE SURVEYS.

The topographic work of the United States Geological Survey, as stated above, is primarily to furnish a base for a geologic map, and has been carried on where the demand for such maps, particularly of mining regions, is most urgent. For this reason the work has been distributed without reference to state boundaries. Several states, however, recognizing the value of the topographic maps the Federal survey is making, and cognizant of the fact, also, that when once topographic maps are available, detailed geologic and forestry surveys, conducted by the general government usually follow, have been anxious that topographic maps should be made of their entire areas. With this aim in view, several states have arranged to co-operate with the United States Geological Survey in making complete surveys of their respective territories.

The basis for such co-operation is for each party to the agreement to pay one-half of the expenses of the actual survey and for office work in preparing maps for publication. The work to be done by or under the direction of the Federal Survey. In addition to defraying one-half of the field expense, the Federal Survey engraves and prints the finished maps. The edition thus produced, however, is the property of the United States, but the State may order as many copies of the maps as it wishes, for the price of press-work and paper, or, as is usually done, have electrotypes made of the original plates and print its own edition.

The expense to co-operating states for copies of the final map-plates, is thus considerably less than their total cost, and not over one-fourth what it would cost a state to organize an independent survey and do the same work. The reason why it would be much more expensive for a state to survey and map its own territory than it would cost the Federal Survey to do the same work, is because the Federal Survey is completely organized, has trained topographers in its corps, and is already provided with instruments, etc.

The states which have taken advantage of the generous offer of the United States Geological Survey referred to above, and now have maps of their respective territories completed or under way, together with the expenditures in each instance, may be seen from the following table:

CO-OPERATIVE TOPOGRAPHIC SURVEYS IN VARIOUS STATES.

State.	Area in square miles.	Area mapped in square miles.	Total cost to June 1901.	Appropriated by State to June, 1901.	Appropriated by State for 1902.	Appropriated by State for 1903.
Massachusetts	8,315	All	$107,845	$40,000		
Connecticut	4,990	All	48,555	25,000		
Rhode Island	1,250	All	9,732	5,000		
New Jersey	7,815	All	54,744	19,670		
Pennsylvania	45,215	10,785	130,260	38,000	$15,000	
New York	49,170	25,802	303,930	151,000	20,000	
Maine	33,040	4,767	38,985	10,000	2,500	
Maryland	12,210	10,307	57,250	17,000	6,000	
Ohio	42,050	1,864	12,000	25,000	20,000	$30,000
North Carolina	52,250	12,252	....	20,000	5,000	
West Virginia	24,780	17,227	....	30,000	5,000	
Michigan	58,915	....	....	....	2,000	
Alabama	52,250	....	....	3,000		
Mississippi	46,810	....	....	....	1,000	
Texas	265,760	....	....	....	2,500	

As is indicated in the above table, four states have maps of their respective areas complete, and eleven other states have declared their intention, as it were, to supply their citizens with the aid to both commercial and educational development which such maps afford.

TOPOGRAPHIC SURVEYS BY THE UNITED STATES GEOLOGICAL SURVEY IN MICHIGAN.

In the iron districts of the Northern Peninsula of Michigan, large-scale contour topographic maps have been made by the United States Geological Survey of areas aggregating nearly 2.000 square miles. This important work was done in order to furnish satisfactory base-maps for use in making detailed studies, particularly of the geology of the iron bearing rocks. Very complete and accurate reports on these investigations have been published, accompanied by both topographic and geologic maps without cost to the State of Michigan.*

*The Marquette iron-bearing district of Michigan, with atlas, by Charles Richard Van Hise and William Shirley Bayley, including a chapter on the Republic Trough by Henry Lloyd Smith, Washington, D. C., Government Printing Office. 1897, quarto, pages I-XXVI, 1-608, and folio atlas of 39 sheets. Price $5.75.

Geological Atlas of the United States, Menominee special folio. Michigan. Folio No. 62, by C. R. Van Hise and W. S. Bayley. Size 18 by 21 inches, 13 pages of text; one topographic arid one geologic map. Price 25 cents.

CO-OPERATIVE TOPOGRAPHIC SURVEYS IN MICHIGAN.

In 1901 and 1902 a topographic survey was made by the United States Geological Survey, in co-operation with the Geological Survey of Michigan, of an area of 910 square miles, in the Southern Peninsula of Michigan, and including the region about Ann Arbor, Ypsilanti, etc. The work was done under the immediate direction of Mr. Robert Muldrow, to whose skill and efficiency much credit is due from the citizens of this State. The map on which the results of this work are shown, is termed a thirty-minute sheet, that is, it includes one-half a degree of latitude and one-half a degree of longitude, is drawn to scale of about two mites to one inch or $^{1}/_{125000}$ nature, with 20-foot contour intervals. It is to be printed in three colors, uniform with the other sheet of the "Topographic Atlas of the United States," and designed at the Ann Arbor quadrangle. In addition to the map now in hand, bench-marks, giving the precise elevation above the sea, have been placed at many convenient localities throughout the region it represents; these will be of assistance in making local detailed surveys for various purposes, and serve to unite in one system all surveys based on them.

The expense for field work for the map just described, was $6,482.47, and for office work in preparing the data for publication, about $400.00; making the total cost approximately $6,880.00. Of this sum $2,000.00 was paid from the appropriation made by the State Legislature, for the Geological Survey of Michigan, and the remainder by the United States Geological Survey. The total cost per square mile was about $7.55, or a trifle over one cent per acre. The State of Michigan is entitled to have a reproduction made of the original copper plate from which the map is to be printed, if it so desires, or as is the rule with all publications issued by the Federal government, may order as many prints from the original plate as is required, at the cost of press work and paper. Individual copies of the Ann Arbor quadrangle will be sold by the United States Geological Survey at five cents each; and may be obtained in numbers exceeding 100 for two cents per sheet.

The map now completed of the region about Ann Arbor and Ypsilanti, is an admirable piece of cartographic work, and one for which the citizens of that region should be very grateful. Its accuracy and value have been recognized by all competent judges who have examined it. In this connection I am permitted to make public the following testimonials:

M. S. W. Jefferson, Professor of Geography in the Normal College at Ypsilanti, writes:

"The map of the Ann Arbor quadrangle is to the students of geography in the Michigan Normal College, what a natural history museum is to students of biology. On it are represented a large variety of topographic forms such as morainal hills, stream-cut valleys, abandoned lake beaches, lake plains, etc., which our students quickly learn to recognize and to enquire as to the history and meaning of. The map on account of its home relations, furnishes an aid in teaching such as no map of a distant region, however instructive, can supply."

Mr. Frank Leverett, of the United States Geological Survey, who for several years has been engaged in the detailed investigation of the surface geology of the region drained by the Ohio, etc., and has devoted three years to the study of the surface geology of Michigan, writes in the above connection as follows:

"The map of the Ann Arbor quadrangle, recently completed, will be of great service in interpreting the glacial history of the region it represents, as it sets forth in an admirable manner the features of the land produced by the ice sheet which once covered it. The map indicates clearly the moraines, lines of glacial drainage, the former outlines of lakes, the extent of swamps and other features of both scientific and economic importance. Its excellence should create a demand for the rapid extension of the survey on which it is based, to all parts of Michigan."

As to the value to the students of the University of Michigan, of the map referred to above, I can say without reserve/that it is all that can be asked, and will not only stimulate study, but aid in an important way in original research. To students of geology and geography if furnishes a picture of a considerable variety of topographic forms, the origin of which may be studied to advantage with its aid. To students of engineering it supplies an example of work in a highly specialized branch of surveying, and may be used in making preliminary or trial locations for railroads, trolley lines, sites for reservoirs, etc. To the students of botany and zoology it provides a base for accurately plotting the distribution of plants and animals, arid for determining the conditions on which such distribution depends. In these and other ways the map of the environs of the University of Michigan will be an assistance and inspiration to her students for many generations to come.

To the citizens of Ann Arbor, Ypsilanti and other towns situated within the area represented on the Ann Arbor quadrangle, it supplies all the data for the study of sources of water supply, sewer systems, pollution of streams, drainage of swamps, etc., that could be obtained by costly preliminary surveys.

THE CONTINUATION OF THE CO-OPERATIVE TOPOGRAPHIC SURVEY OF MICHIGAN.

The topographic maps of nearly 2,000 square miles of territory in the Northern Peninsula, and of 910 square miles in the Southern Peninsula, now in hand, make a substantial beginning of what it is earnestly to be hoped will eventually result in the production of a map of similar grade of our entire State.

As already explained, the maps of the mineral regions of the Northern Peninsula, were made without assistance from the State of Michigan. Less than one-third of the expense of the surveys for the Ann Arbor quadrangle, was paid for from an appropriation made by the Legislature for the continuation of the State Geological Survey and wisely allotted by the Board of Geological Survey for the securing of a suitable map for the use of our State geologists.

Thus far, however, no direct appropriation has been made by the Legislature of Michigan for co-operation with the United States Geological Survey, for the purpose of carrying on topographic work within the State. It is on this direct recognition and assistance by the Legislature that the continuation of the surveys referred to depends.

The estimated cost of making the topographic map of Michigan on the scale and with the degree of excellence that characterizes the portion already completed, is $8.00 per square mile; making the total expense for field and office work about $450,000.00, and the total cost to the State $225,000.00. While the total expense for a complete map of the State may seem large, it is to be remembered that the work will of necessity be distributed over a period of many years, thus making the yearly expenditure moderate. The immediate demand for a topographic survey is not the same for all sections of the State, but is great in certain portions and small in others. In view of this difference in demands, the wisest plan seems to be to have surveys made first where the necessities are most pressing, as for example, where a knowledge of the topographic conditions is important in reference to municipal improvements, drainage, education, etc., in the mining centers like the coal field of the southern peninsula, and the copper regions of the northern peninsula, and where forestry is the leading industry. As the benefits to be derived from a topographic survey of such portions of the State as have just been indicated is demonstrated, the continuation of the survey to completion will, as there seems but little doubt, be easily secured.

In a bill providing for the continuation of the Geological Survey of Michigan, introduced to the present Legislature, an item is included, appropriating $1,000 per year for two years, to enable that survey to continue to co-operate with the United States Geological Survey, in the preparation of a topographic map of the State. This measure I am sure will receive the hearty approval of the Michigan Academy of Science. Our society contains many, if not a majority, of the men of scientific training in Michigan, and as we may justly claim without egotism, should be looked to by our fellow-citizens for advice and counsel in all matters in which scientific expert knowledge is demanded in public affairs. Any recommendation which the Michigan Academy of Science may see fit to make to the State Legislature, in reference to continuing the topographic survey of Michigan, I am confident would be gratefully received by that body, and would exert an important influence in determining its action in reference thereto.

THE CHEMICAL INDUSTRIES OF MICHIGAN.

ALFRED H. WHITE, UNIVERSITY OF MICHIGAN.

It is perhaps advisable at the beginning of this paper to recognize that there is a great difference in the lists of those industries which *are* actually chemical industries and those which *ought* to be chemical industries, but unfortunately are not conducted in such a way as to entitle them to that distinction. The manufacturers of metallurgical, electrochemical, and pharmaceutical products, of alkalies, cements, sugar and varnishes have always recognized the necessity of strict chemical control of their operations.

There are instances of well-conducted works in every other industry, and the large and flourishing factories are almost always found to be under chemical control. The pressure of competition of these modern factories is causing continually larger numbers of manufacturers to break away from the rule of thumb methods handed down by tradition, and to seek the aid of scientifically trained men in the conduct of their business.

The recent completion of the reports on manufactures of the twelfth census allows us to review with some reliability the status of the chemical industries of Michigan. Under the heading "Chemicals and Allied Products" we find the following list in the Census Bulletin:

Industry.	Value of product.
Sodas	$2,826,377
Potashes	77,609
Alums	39,500
Wood Distillation	514,106
Fertilizers	353,608
Bleaching Materials	62,387
Electrochemical Products	193,256
Tanning Materials	100,684
Paints, Colors and Varnishes	3,391,773
Explosives	691,766
Essential Oils	202,258
Compressed and Liquefied Gases	2,976
Chemicals not otherwise specified	1,300,784
	$9,757,084

Michigan ranks as the sixth State in the Union in the value of chemical products thus enumerated, being surpassed by New York, Pennsylvania; New Jersey, Ohio, and Illinois, standing in the order named. In the average number of people employed, however, Michigan takes fourth place, surpassing both Ohio and Illinois.

It will be noted that the paint, color and varnish industry ranked first in the value of its products during the census year, with soda manufacture in the second place. These positions have probably been reversed by the great enlargement of the works of the Solvay Process Company near Detroit, which will probably this year, 1903, give Michigan first rank in the United States as a producer of soda ash. This list contains only a small number of the chemical industries. It does not include the product of the large Detroit manufacturers of pharmaceutical supplies, which are elsewhere listed as producing $4,921,913 worth of goods during the year. Neither does it include the tanning of leather (product valued at $6,015,590), manufacture of soap and candles ($700,238), the production of malt liquors ($5,296,825), nor the manufacture of illuminating gas and its by-products ($1.388,585), all of which are, or at least ought to be, chemical industries.

Especial attention may well be directed to two of the most important and rapidly growing chemical industries in the State—cement and sugar —which rely upon the chemist's knowledge and upon chemical control in every step of the manufacture. The strides made by these industries in the last five years have been enormous.

Portland cement has been manufactured at a few places in this State for many years, but it was not till 1898 that it commenced to develop into a great industry. The following table shows the increase in production and value of product with each year.

PORTLAND CEMENT PRODUCTION IN MICHIGAN.

	Bbls. of 400 lbs.	Value.
1898	81,500	$162,125
1899	402,000	701,000
1900	598,407	831,786
1901	1,025,718	1,128,290
1902	....	....

Michigan stands third among the States as a producer of Portland cement; Pennsylvania being far ahead, and New Jersey coming second with an output not much greater than Michigan.

SUGAR.

The sugar industry in this State is entirely a growth of the last five years. The first factory commenced operations in the fall of 1898, and in the campaign of 1898-99 produced 5,271,000 pounds of white sugar. During the past campaign of 1902-3, there were sixteen factories in operation arid the estimated production was 100,000,000 pounds.

	Factories in operation.	Production in pounds.
1898-9	1	5,271,000
1899-1900	8	32,737,098
1900-1901	10	64,616,358
1901-1902	13	104,590,080
1902-1903	16	100,000,000

The value of the last campaign's sugar was about $4,500,000.

The excessive rainfall of last summer made the season a disastrous one for both beet growers and manufacturers, and kept the industry from showing the large increase in product which it would have in a normal season. As it is, Michigan last year produced about three-fourths of the sugar it consumed, and if the coining season is a favorable one, will have sugar for export after having satisfied the home demands. Michigan ranks as the second State in the Union in the production of beet sugar, producing almost thirty per cent, of the total amount manufactured. California stands first, producing about thirty-six per cent, of the total, but this year would have lost its supremacy to Michigan had the crop in this State been at all favorable.

It is interesting to note how one industry brings others in its train. The forests of Michigan with cheap charcoal brought the charcoal iron furnaces to this State, and the last census reports seven establishments as still in existence, with an output during the census year valued at $2,327,153, which is about two-fifths of the total value of the United States product. The charcoal burners have collected more and more carefully as competition pressed them, the acetic acid and methyl alcohol from their kilns, until now in a well-conducted works the value of the once neglected by-products has become greater than the charcoal. Furthermore, since small wood yields almost as much of these products as good lumber, one of the largest saw-mills of the State has recently installed an expensive chemical works to take care of the slabs and refuse from the mill, where methyl alcohol and calcium acetate are principal products, and charcoal a by-product.

In a somewhat similar way the ammonia produced in the destructive distillation of coal and wasted from the old beehive coke furnaces has become such a valuable product that the Solvay Process Company has extended its by-product coke oven plant to such an extent that it has a large amount of gas to sell to the Detroit Gas Company, and has brought about the erection of an iron furnace near its plant to take care of its surplus coke. Michigan will then appear as a producer of coke pig iron as well as the charcoal iron.

The magnitude of Michigan's copper industry is well known. Not all the product of her mines is refined in this State, but the census returns show three copper smelting and refining establishments with an output of refined copper valued at $17,340,041.

The electrochemical industries of Michigan should be mentioned not so much because of the present value of their products as because of their promise for the future. The tendency of these industries has been to collect around sources of cheap water power, and their concentration at Niagara is well known. The recent completion of the American power canals at Sault Sainte Marie with its 40,000 available horse power has already attracted some manufacturers and plants for the manufacture of alkali and bleaching powder, calcium carbide, and for the electrolytic refining of copper and nickel are reported to be making arrangements to locate there. There is abundant room for the erection of plants for the production of bleaching powder in this country, nearly seventy-five per cent. of the amount consumed being imported. The factories at Niagara produce most of this, but Michigan ranked second in output during the census year. The raw material, salt, is cheaper in Michigan than in any other State, and Michigan has almost continuously taken the lead in its production. It is worthy of note that this industry has developed in this State without the advantage of cheap water power and that though the water power at the "Soo" is attracting some manufacturers, others have decided it is more economical to locate near the markets and salt deposits, as is shown by the erection of the large plant now nearly completed of the Pennsylvania Salt Manufacturing Company at Wyandotte.

If we summarize these industries we find for the value of the products of the chemical industries of Michigan for the census year (except for cement and sugar for which later values are given):—

Soda, Bleaching Materials, and Electrochemical Products..	$3,080,020
Paints, colors and varnishes........................	3,391,773
Other industries included in Census Bulletin on "Chemical and Allied Products"........................	3,285,291
Druggists' Preparations	4,291,913
Tanning of Leather, etc........................	6,015,590
Soap and Candles	706,238
Malt Liquors	5,296,825
Illuminating Gas and By-products........................	1,388,585
Portland Cement (1902 estimated)........................	2,500,000
Sugar (1902-3 estimated)........................	4,500,000
Pig Iron	2,327,153
Refined Copper	17,340,041
	$54,123,429

There are very few States, notably New York and Pennsylvania, which surpass Michigan in the variety and magnitude of their chemical industries. Michigan's advance in this line during the past ten years has been extraordinary and the State seems destined to more than hold its own in the future.

HISTORICAL REVIEW OF THE GEOLOGY OF MICHIGAN.

A. C. LANE, STATE GEOLOGIST, LANSING, MICH.

The earliest published work referring to the Geology of Michigan was read before the Geological Society of London in February and March, 1823,[1] before Michigan had become a State and indeed, before the territory now comprising the State had been entirely released by Great Britain.[2]

Dr. Bigsby was surgeon on Drummond Island at Fort Drummond which was still held by the British. In this report are already identified and separated; the Lake Superior sandstone; "the limestone of St. Joseph," which we now" call the Trenton; the "limestone of the Manitouline," which has been since known as the Niagara; the gypsum deposits of the Isles of St. Martin which represent the Salina and the "cavernous and brecciated limestone of Michilimackinac," which was later called the Helderberg. It will be noticed that these names have since been replaced by names from New York localities which possess more or less equivalent rocks, but I think the time is at hand when we shall see clearly that these names are not really equivalent in their New York and western usage and shall return for our western usage to those old names, which have priority anyway. He describes a number of fossils and gives a careful description of the petrographic character of these different layers. For nearly twenty years there was no addition to our systematic knowledge. Then the Geological Survey under Douglass Houghton began.[3] The proceedings of this Survey are scattered through a lot of House and Senate documents and are almost impossible to obtain. For this reason they have not received the attention they deserve, both as to surface and general geology. Moreover, the work was interrupted by the death of Dr. Houghton in 1847, and many of the illustrations never saw the light. By this Survey the coasts of both Peninsulas were carefully skirted and the presence of coal in the interior of the Lower Peninsula and the general distribution of the copper bearing rocks and the iron bearing rocks of the Upper Peninsula were laid out. Originally, the circular basin like arrangement of the beds in the Lower Peninsula was not understood, but before their work was finished they had arrived at correct views.[4]

Houghton had just arranged for a system of co-operation with the U. S. Land Office in the Upper Peninsula, by which geological observations were to be made in connection with their subdivision. This very promising plan was never thoroughly carried out, but a mass of information was accumulated which enabled the next Geologists to publish, to cover and get practically correct a vast amount of territory.

The general government next took a hand, and under C. T. Jackson[3] and Foster and Whitney3 a report was prepared which included much of the work of Houghton and his assistants and covered the Upper Peninsula with a considerable degree of accuracy. They were assisted by Desor on surface geology and James Hall on the paleontology and sedimentaries, and also by Burt and Hubbard of the Michigan Survey and Williams, Stevens and Hill. Let us compare the amount of information attained at this date. The broad bands of sedimentaries in the eastern half of the Upper Peninsula sweep around substantially as they do on my latest map. No finer subdivisions have been made in the sedimentaries and no material error has been corrected with the one exception that the upper Helderberg of the Devonian System is extended much too far north. Passing to the pre-Cambrian rocks we find the great range of copper bearing rocks, which, by the way, were then classed with the Silurian, extending from Keweenaw Point to the Wisconsin line and dipping towards Lake Superior and re-appearing on the other side of Lake Superior in Isle Royal where they dip to the southeast. The rocks prior to the copper bearing rocks are divided into crystalline schists and granite, corresponding roughly, but with fair distinctness with the Laurentian or Basement complex and the Huronian or Lower Algonkian of later writers. The main questions left, which were not altogether settled to the entire satisfaction of everyone, are as follows: What are the relations of the red sandstones which appear both to the northwest and southeast of the Keweenawan Copper Range and how nearly are they the same? What are the mutual relations of the sedimentary and igneous rocks associated in the Azoic system, which Dana later called Archean, and what are the details of the stratigraphy? The geology of the Upper Peninsula as left by Foster and Whitney[2] was as well or better known than that of the Lower Peninsula, and its mineral wealth .attracted the attention of the mining men of Europe. Fr. C. L. Koch[5] gave an account of his trip and a map, which though based upon Foster and Whitney, gives considerable more detail in some parts and gives a more accurate petrographic description of the melaphyres or traps and amygdaloids of the copper bearing rocks. Rivot,[6] a French geologist, also made a trip but the observations of these geologists had little effect on the course of progress for they were overlooked and rediscovered independently by later writers.

With the revival of the Geological Survey under Alexander Winchell interest and progress is shifted to the Lower Peninsula and his report,[7] issued in 1861, contains a clear and generally accurate account of the general stratigraphy of the Lower Peninsula, with a mass of further information regarding the occurrence of coal and salt. Though this report contains no geological map, it should be read in connection with the articles[8] on Michigan and the maps prepared therewith, which he prepared for the Walling-Tackaberry Atlas, issued in 1864-5, 1866, 1873. By this time the general outline of the Coal Basin had been determined, and the general basin-like structure and the principal horizons of the succession of rocks beneath. The only thing that can be said in a general criticism is that the thickness of the various formations was uniformly underrated. One point occupied Winchell's time and attention for a number of years and a series of papers,[9] and that was the Marshall Group. The state of affairs is about as follows: New York was the first State in which the Paleozoic column was thoroughly worked out in detail and it has been used as a norm by geologists of other States. In that State we find, beginning at the base of the upper Devonian with a black shale, a series first of blue shales, then of fine-grained bluish and greenish sandstone growing coarser and coarser and culminating in red beds and conglomerates, and emergence of the land and a cessation of deposits. This series is known as the Portage-Chemung-Catskill, and all these rocks are supposed to belong to the Devonian, representing plainly part of one physiographic cycle. Now when we come to Michigan we find a similar lithological and physiographic succession. Beginning with the black shales, which Winchell called Huron, and we now call Antrim, we have a similar succession passing through blue shale, blue and green sandy shales and sandstone to heavy sandstone. It was natural for the New York Geologists to correlate them with their own series, but Winchell found that the uppermost beds of this series, which he called the Marshall Group, were fossilferous, especially in the lower part, the upper part being a heavy sandstone in which fossils are rare. These fossils he maintained were distinctly Carboniferous in character and though the controversy lasted some time there is no doubt that he was right, so that at least the upper part of this series must be put into the Carboniferous, just how much it is often hard to tell. We have here a case in which the progress of geographic evolution and that of organic evolution did not keep pace. The continent emerged earlier in New York than in Michigan and the fauna did not migrate paripassu.

We have now the geology of the State mapped out in broad and general outlines, except that very little was yet known regarding the detailed superficial geology, except that the lakes had once been higher and retired and that the ice had once played a much greater role in distributing erratics. Mr. Leverett takes up this matter so that for me there remains only to describe the work of correction and filling in, and yet this is of no mean importance, either theoretically or practically. The next geological survey was started in 1869. It is worthy of remark that just as Michigan has very strong State Institutions, while the private colleges are comparatively weak, so most of what has been done geologically, has been done officially, and we have not had that wealth of information which in other States has come from private initiative. One exception to this is in the work of the Kent Scientific Institute about at this time,—another is of the Lake Superior Mining Institute at present. Of course much of the scientific information has been gathered by State Officers from developments made for private ends, with their testings, drillings, etc. In 1869 the Survey as re-organized[10] had Alexander Winchell at its head, but the laboring oars were taken by Brooks on the iron bearing rocks, Pumpelly on the copper bearing rocks, and Rominger on the sedimentaries. Mr. Brooks' work introduced to the field a number of names prominent here and elsewhere, such as H. Credner, A. A. Julien, Chas. A. Wright, Regent C. D. Lawton, Jacob Houghton and others. It contains a valuable treatise on the tracing out of the stratigraphy of the very complicated iron regions by means of belts of magnetic attraction. It contains also a lot of microscopic descriptions which should mostly be replaced by later and more accurate work of the U. S. Geological Survey. In the field the distinction between the hornblende and augite was not satisfactorily made and the geological relationships of the rocks called diorites, which are largely altered augitic rocks was not understood. Nevertheless, in the matter of detailed stratigraphy of the iron bearing rocks, very great progress was made and a mass of material regarding methods, mines and electrical relations has historical value.

Pumpelly with Credner,[11] who has been for years one of the most distinguished of the German Geologists, furnished much of the material for the description of the Menominee Iron Region, but it would be well before taking up the work in oilier fields to consider the progress of knowledge in the Marquette Range. This field is the earliest opened and most extensively studied, and has naturally been the Mecca for numerous geologists who intended to apply information collected here to other regions, and so we have references to the facts upon this range and inferences founded upon them, which depend upon first hand information and actual observation, very widely scattered in geological literature.[12] Our brethren in Wisconsin, Minnesota and Canada have certainly similar rocks and similar problems, a successful attack on one of which in one place will be likely to modify conceptions all along the line.

Among the rocks of the Archean we find coarse grained plutonic rocks, granites, syenites and peridotites which are mainly attributed to the lowest part of the formation,—the Laurentian of the earlier writers, a term introduced from Canada which I think we should still keep. In this lower group there are also gneiss and schists and possibly narrow bands of rocks like those above. The stratigraphic relations are of ineffable complexity and we have not begun to decipher them. Van Hise called them the Basement Complex and suggested that if there is such a thing visible, they may be part of the original crust of the earth. Above this Laurentian comes the iron bearing series proper, called the Huronian. Beside the familiar types of rock such as black slate, dolomite and quartzite passing into conglomerate, there are two important types which require especial attention. There are at first a lot of dark colored rocks composed of hornblende with more or less lime soda feld spar, chlorite and numerous other minor constituents. Instead of the hornblende there is often augite. The hornblende is in fact in most cases a product of alteration from the augite, though various authors have overlooked the augite entirely, and others have considered the hornblende, which some consider as secondary, as primary. There is also a question about this group of rocks as to whether they are stratified members or a series of sediments or igneous intrusives, and about the points just mentioned along and at times acrimonious difference of opinion has developed, beginning with Brooks and his assistants Julien and Wright and continuing through papers by Wadsworth, G. H. Williams and Van Hise, Smyth and Clements down to the present day. Personally I should summarize the matter as in the following paragraph and the U. S. Geologists would now, I believe, agree with me in the general conclusions, though we may still differ in specific applications.

There is a number of different types of the group of rocks above mentioned, most of which are undoubtedly igneous,—flows, intrusions or dykes in the iron bearing series and originally, mainly augitic. In the first place, it is relatively easy to cut out a group of dykes which cut through all members of the iron bearing series and whose augite is usually very little altered. They are the old feeders to the series of Copper-bearing Rocks arid are subsequent to the formation and much of the distortion of the iron bearing series. Secondly, we have dykes which are similar, but cut by the former set, of a different prevailing strike, whose augite is more altered, which may be considered as similar dykes of diabase, but coeval with some later part of the iron bearing series. Thirdly, we have masses of similar rock which is usually called diorite, along the cleavage or stratification of the iron bearing sediments. They are not infrequently the foot-wall of bodies of iron ore. In them the augite is generally very largely changed and sometimes instead of being a granular mass of hornblende and feldspar, popularly known as diorite, they become more uniform in color (greenstone) or are crushed and changed still further so as to be highly foliated and pass under the names of chlorite schists, soap stone, paint rock, etc. These masses were originally probably like the traps of New Jersey, and some of them intrusive like the Palisades of the Hudson and others effusive. The amount of secondary alteration makes the problem of determining which a difficult one, not yet systematically solved. Finally, in connection with the effusive sheets there are undoubtedly beds of tuff and sedimentary beds composed of altered trap fragments. I think there is no doubt that all these classes exist but some authors are inclined to see greenstone sediments everywhere and others to refer all doubtful cases to the igneous rocks. Some of these traps undoubtedly have altered the adjacent rocks as I have elsewhere remarked, and I believe a good deal of light will be thrown upon this matter by study of the effects of baking and contact metamorphism and the subsequent alterations. Little has been done in this line yet.

Another rather exceptional group of rocks are those in which some of the ore deposits occur, which have been called by Wadsworth, jaspilite,—a rock largely composed of silica. It bears a strong resemblance to some red porphyries or rhyolites and on account of that and some apparent igneous contact with schists, Dr. Wadsworth took it for an igneous rock and thus spoke of the igneous origin of iron ores. Perhaps all geologists are, however, now agreed that in the contacts spoken of, the apparently stratified and sedimentary schists are really the igneous rock and the jaspilite is the sedimentary. The greatest light upon the origin of the jaspilite has been thrown by Van Hise and Irving, who worked into the problem from the Penokee-Gogebic Range of Wisconsin and Michigan, where the stratigraphy is comparatively simple. Their theory, which is doubtless in large part true, is that the original rock of the jaspilite was a cherty iron carbonate. In limestones deposits of chert are very frequent and in the coal measures, beds of iron carbonate, known as black band iron ore, are of a well known type, so that there is nothing forced in the supposition made by Van Hise. We then have to suppose that these beds have been altered by the action of water and Van Hise has pointed out with great detail from the results furnished him by the engineers of many of the extensively exploited iron deposits that the iron ore rests in troughs made by impervious rocks, such as the soap stone above mentioned or slate, down which the waters percolate. The silica and carbonates have been removed and the iron ore concentrated. This concentration of iron ore bodies is, however, not confined to the jaspilite formation but occurs in several different horizons and particularly at the bottom of the formation whenever the structural conditions are favorable; for instance, often replacing the Goodrich Quartzite which lies at the base of one of the iron series.

This brings us to another question, that of the subdivision of the iron bearing or Huronian series. Over this question there has been also a long controversy, participated in by various writers, and it cannot yet be said to be fully settled. I believe, however, that we are within sight of agreement on the great essentials. Mr. Van Hise is preparing a final monograph on the iron ores of Lake Superior, and I think that in that he will assume a position with which I can coincide in all the essential fundamentals. I copy from his report on the iron ore deposits of the Lake Superior Region in the Twenty-first Annual Report, a table slightly modified, the modifications which I have made being indicated by italics. It will be noticed that he has already introduced the possibility of sediments and iron bearing formations into the lowest division,—his Archean,—my Laurentian, which is a modification of his earlier position.

Cambrian	Lake Superior Sandstone.
(Unconformity)	
Upper Huronian, (Upper Marquette Series.) Rominger's Lake Hanbury?	Michigamme formation (locally replaced by Clarksburg volcanic formation). One might divide the Michigamme sedimentary formation into three parts: (a) upper slate member, (b) iron-bearing member, (c) lower slate member. Ishpeming formation, consisting of two members: the Bijiki schist (in western part of district), and the Goodrich quartzite, containing detrital ores at its base.
(Unconformity)	
Middle Huronian. Rominger's Quinnesec?	Negaunee formation. (The chief iron bearing formation.) Siamo slate, containing interstratified amygdaloid. Ajibik quartzite.
(*Unconformity*)	
Lower Huronian, (Lower Marquette Series.) Rominger's Norway?	Wewe Slate. Kona dolomite. Mesnard quartzite.
(Unconformity)	
(Laurentian.)	Granite, syenite, peridotite. Kitchi schist and Mona schist, the latter banded, and in a few places containing narrow bands of iron bearing formation. Palmer gneiss.

The iron bearing series and all three members of the Huronian have in many places been folded and a slaty cleavage produced which has been mistaken for the original bedding. They are probably least disturbed to the west in the Gogebic Range, where they occur in a fairly regular band with Laurentian rocks to the south and the Copper-bearing rocks to the north. Above them and generally unconformable come the rocks of the Copper-bearing series. Their distribution was fairly accurately outlined by Dr. Houghton and his assistants,—Burt and Hubbard—and it is summarized in the work of Foster and Whitney. Their mineralogical character was quite accurately determined by Koch and in fact, except for fine distinctions, is very simple. We have a series of flows of lava; the center massive, the top originally porous and full of bubbles which are generally filled in so as to produce a spotted appearance. The commonest minerals are augite and a lime-soda feld spar. Olivine seems to have been frequently present but is generally altered. There also occur masses of more silicious rock, felsites and rhyelites. Usually one sheet is directly piled on another, but occasionally the igneous activity which poured them forth paused long enough to allow the formation of a small bed of sandstone or conglomerate. Toward the upper part of the formation as the igneous activity died out. the sandstones and conglomerates become more and more important until finally the top of the formation is almost entirely composed of red sandstone and shale. This is found on the south side of Isle Royal and on the south shore of Lake Superior west of Portage Lake. So much was early settled. Two or three points remain the subject of controversy and one of them is not yet settled.

We have said that the top of the formation is a red sandstone. Is this the same as or immediately beneath and earlier than the red sandstone which occurs around the east end of Lake Superior as the base of its Paleozoic there, and is of the Upper Cambrian Age, or is it separated by a long interval of time and unconformity, so that for it an age should be carved out beneath the Cambrian, to which the term Algonkian should be applied? To this question, no positive answer can yet be given. It remains for the future to decide and no fossils have been found or are likely to be found in such a great series of sandstone. On lithological grounds these sandstones have been given ages till the way from the New Red, down. The Minnesota Geologists attribute then), to the-Cambrian. The U. S. Geologists to the Algonkian. The Upper Keweenawan differs in a more basic character, a somewhat greater induration and, judging from the Freda Well, in salty water from the typical Potsdam or Lake Superior Sandstone. But on the other hand, the tendency to approach the Lake Superior Sandstone, both in lithological character and in structural conditions as we ascend in the Copper Bearing Series, is well marked. We have a great outpour of igneous rock beneath, a concomitant, depression, the igneous activity dies out but the depression continues, and those parts of the igneous rocks which were exposed to erosion or eroded and form a sandstone. This epoch of depression seems to continue until the whole basin is swathed in sandstone, which is represented by the Lake Superior Sandstone. It is not to be expected that the upper part of this sandstone would contain so much trace of the igneous rocks. Now, when we find the upper part of the Keweenawan representing a depression and we find the upper part of the Cambrian also representing an era of depression, which might well be the continuation of the same, is there any good reason for supposing an era of time to intervene which shall represent at least the middle and lower Cambrian? Before we can fairly estimate the argument for the affirmative we must consider the second great question around which discussion so far the Copper Bearing Rocks are concerned has turned. The relations of the Keweenawan Copper Range to the rocks flanking in on the north are very simple. The beds all dip the same way and while there are minor unconformities, such as will be expected in a series of igneous rocks and is indicated by the pebbles and the conglomerate, still there appears to be no great break. On the south side of the Range, however, the relations are much more complex. There are two or three places where sandstone distinctly laps over onto the upturned edges of the Copper Bearing Rocks. There are other places, notably Douglass Houghton Ravine, where the sandstones, generally called Eastern Sandstones, appear to dip directly and conformably beneath the Copper Bearing Series, although I think that in such cases a careful study of sufficient exposures will always show sign of faulting and that the contact is really made by an overthrust fault. Finally, there are other places which lend color to the view of Agassiz and Pumpelly, where the sandstone seems to abut against the trap range, as a conglomerate might against the cliff from which it was formed and finally there are numerous other places where the contact is plainly one of faulting and the beds of the Eastern Sandstones are variously crumpled. Into the details of the long controversy which has been the subject of a special bulletin (No. 23 of the U. S. G. S.) I will not go, but will merely state what I consider to be now proved and probable.

First, There is a, large fault and smaller subsidiary faults running along the southeast side of the Keweenawan

Range. There is no reason why slipping and disturbance on this plane may not have occurred from time to time down to at least as late as the stresses which produced a small sharp infold of Niagara and Trenton Limestone, in Limestone Mountain not far off. On the other hand it is certain that the disturbance there began before the end of the formation of the Eastern Sandstone which in some cases laps over on the disturbed strata. Not only that, but I consider it quite likely that the disturbance along this line began before the close of the Keweenawan and that the vents from which came some of the Keweenawan flows may have lain close to this line. It is not without significance in this connection that at Mt. Bohemia we find close to the fault line an old igneous plug which has altered the rocks which it has invaded.

Another question concerns the origin of the copper. Its association built in alternating layers of calcite and side by side with silver unalloyed, prove that it was laid down in a wet way. The association of copper with similar traps in a great many parts of the world leads one to look to them as in a broad way at least to the source of the copper. The olivine which is so largely decomposed sometimes contains small quantities of copper and nickel, and Pumpelly, without a doubt, ascribed the concentration of the copper to downward percolating waters which have decomposed the traps and concentrated the copper. In this I am inclined to agree with him, but Smyth looks to deeper seated hot waters for the source of the copper. The copper bearing formation is tilted and fractured but not contorted. The fractures that run across the formation are easy to detect but those which run with the beds are merely slipping of one bed upon another as the leaves of a book would slip when bent, or, have the same strike as the beds but a steeper dip, are very hard to detect. The progress in mining has, however, shown that they are very wide spread and slickenslides with chloritic walls are not at all uncommon. I think they guided the copper deposition. There is a theory among practical mining men that the copper occurs under high ground, and if this is true it will favor Pumpelly's theory, for the downward circulation would there be most active.

The third part of Vol. Ill is devoted to a further study of the sedimentaries of the eastern half of the Upper Peninsula by Dr. Carl Rominger, now a resident of Ann Arbor, who became and remained State Geologist for some twenty years. He added a good deal to our knowledge of the paleontology of the belts, but did not materially change their distribution or subdivision, in fact, he was less inclined to minute division than Winchell. In Vol. Ill he transferred his studies to the Lower Peninsula, and this volume is a treasure house of observations upon the rock geology of the Lower Peninsula. One has to be thorough to find any rock exposures which he did not visit. He made also extensive collections of fossils, and the second part of the volume contains elaborately illustrated paper on corals. Dr. Rominger gives us not a few records of deep wells, and an appendix contributed by Dr. Garrigues calls attention to the different chemical character of the brines.[13] They also begin to appreciate how much thicker the geological column is than Winchell had been able to estimate from surface observations. Dr. Chas. R. Wright succeeded Dr. Rominger and when he died, leaving matters unfinished, I had to take up and prepare for publication the records which he had gathered during the great drilling excitement of 1885-7. This added a bundle of new facts which were incorporated in Part II of Vol. V, and my papers on the Water Supply of this State.

Little by little the drill, going down now for salt, now for oil or gas, now for water for the farm or city, or for mineral water, has added to our knowledge of the geology of the Lower Peninsula and enabled us to improve a little upon the boundaries laid out by the first geologists, yet in the main their work has stood the test of time. The main factor which is coming out is that there are minor flexures in the general basin like structure which was correctly found by the earlier Surveys. This shows in some of the cross sections given in my Coal Report. In regard to the salt, the following different brines may now be distinctly recognized:

1. The brine of the Parma Sandstone and the Grand Rapids Group, which is high in sulphates.
2. The brine of the Marshall Group, which is relatively free from sulphates but contains the earthy chlorides and valuable amounts of bromine.
3. The brine of the Berea Grit. This was perhaps first identified as such by Rominger in the old Ann Arbor well, but is also the source of the Huron County brines.
4. Brines of the Traverse and Dundee, the Devonian Limestones. Gas and oil are liable to be associated with these and particularly H_2S.
5. Beneath this comes the rock salt from which a brine is derived by letting down water from the surface.

There are of course other brines in Niagara and Trenton, but these are those of most commercial importance.

Much exploration has been carried on for oil and gas, but it has been very largely on the strength of surface deposits or signs and the results have been disappointing except near Port Huron. We have, however, beyond question the oil and gas bearing rocks, and it is only a matter of time when reservoirs of these substances in commercial quantities will be found.

While coal has long been known, it is only recently there has been much developed, and that material for correlation from other regions has been obtained. It proves to belong to the Pottsville formation, formerly known as the Millstone Grit, the oldest in which workable beds occur.

The development of the Portland Cement Industry has recently spread to Michigan, and while drawn here first by deposits of marl, one of our surface deposits to be treated by another, I think it will be found that the State possesses limestones and shales which will be of great value to her in this connection.

In conclusion, as I have already given a brief summary of the formations below the Cambrian, I may give the rest of the geological column beginning with the Bay City Well and continuing with a new well at Port Huron, then taking up the Cheboygan Well, and then some of the wells along the Lake Michigan shore of the Upper Peninsula.

Coal Measures	380 plus	
Parma Sandstone	50	
Upper Grand Rapids	80 "	
Lower Grand Rapids or Michigan	220	
Upper Marshall or Napoleon	130	
Lower Marshall	320	
Coldwater Shales	760	
Berea Shales	40	
Berea Grit	170	
		2,150

END OF CARBONIFEROUS AND BEGINNING OF DEVONIAN.

Antrim Black Shales	320	
Traverse Group (on St. Clair River)	296	
Dundee Limestone	129	
		745

END OF DEVONIAN AND BEGINNING OF SILURIAN.

Monroe beds, above salt formation	765	
Monroe beds with dolomite, salt, anhydrite	805	
Guelph and Lockport (Niagara) dolomites	600	
Rochester Shale	70	
Clinton	60	
Medina	142	
Lorraine and Utica.....about	500	
Trenton	300	
	3,242	
		6,137

Calciferous has not been separated.

END OF SILURIAN BEGINNING OF CAMBRIAN.

The Lake Superior Sandstone has been bored at Grand Marais and at Lake Linden for over 1,000 feet with no important change.

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[2]Drummond Island, by S. F. Cook. Lansing, 1896.

[3]Publications of the Douglass Houghton Geological Survey.

Reports from 1838-1846 were published with Legislative documents as follows: S. D. means Senate documents; H. D. House documents; J. D. joint documents. State Geologist is abbreviated S. G., and State Geological Survey, S. G. S.

1838. Report of a select committee of the Board of Regents of the University on the collection of the S. G.
H. D. Vol. I, p. 1-2; S. D. No. 1, p. 1. H. D. No. 5 is duplicate of No. 1.
Statement of the expenditures on account of S. G. S. for the year 1837.
H. D. No. 8. pp. 115-118: S. D. No. 21 (First annual account of the S. G.), pp. 315-318.
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H. D. No. 46, pp. 457-460.

1839. Report of the S. G. in relation to the improvement of State Salt Springs.
H. D. No. 2, pp. 39-45; S. D. No. 2, pp. 1-8.
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H. D. No. 4. p. 123.
Report of the S. G. in relation to the iron ore, etc., on the school section in town five south, range seven west, in Branch county.
H. D. No. 21, pp. 342-344.
Second annual report of the State Geologist.
H. D. No. 23, pp. 380-507; S. D. No. 12, pp. 364-391; also separately H. R. No. 23, and S. R. sometimes misprinted No. 13 and No. 23, pp. 39, and appendix of sub-reports 123 pp.
Report of the Committee of the Senate on Manufactures, to whom was referred the communication of the S. G. relative to salt springs and the salines of the State.
S. G. No. 3, pp. 85-86 (parallel to H. D. No. 4).
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1840. Report of S. G. relative to the improvement of the Salt Springs.
H. D. No. 2, Vol. I, pp. 18-23; S. D. No. 8, Vol. II, pp. 153-158.
Annual report of the State Geologist (third, map of Wayne county).
H. D. No. 27, Vol. II, pp. 206-293; S. D. No. 7, Vol. II, pp. 66-153; separately No. 8, pp. 1-124.
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H. D. No. 46, Vol. II, pp. 455-461.
Report of the majority of the Committee on Finance on the communication and accounts of the S. G. for 1839.
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S. D. Nos. 15, 16, 17, 18, pp. 209-224.

1841. Special message concerning State Salt Springs.
H. S. and J. D. No. 5, pp. 235-254.
Annual report of the S. G. (fourth).
H. S. and J. D. No. 11, pp. 472-607; separately H. D. No. 27, pp. 1-184.
Report of the S. G. relative to county state maps.
H. D. No. 35, pp. 94-98.

1842. Report of the S. G. relative to the State Salt Springs.
H. D. No. 2, pp. 15-21; S. D. No. 1, pp. 1-9.
Report of the select committee in relation to the report of the S. G.
H. D. No. 19, pp. 77-79.
Annual report of the S. G. (fifth).
J. D. No. 9, pp. 436-441.

1843. Annual report of S. G. (sixth).
J. D. No. 8, pp. 398-402.
Report of the S. G. relative to the State Salt Springs.
S. D. No. 9, pp. 402-408. Maps of Washtenaw, Calhoun, Jackson and Lenawee Counties were published separately.

1844. Annual report of the S. G. (seventh).
S. D. No. 11 (three pages).
D. Houghton undertook an arrangement with the Linear Survey of the U. S. Land Office by which a certain amount of geological work was done, which was never published by the State, the results of which appear largely in the township plats of the Land Office, and in the report of C. T. Jackson, 1849, U. S. S. Ex. Doc. No. 1, pp. 371-935, H. Ex. Doc. No. 5, Part 3, including sub-reports of W. A. Burt and Bela Hubbard on the geology of the sub-divisions of the Linear Survey, First Session 31st Congress, and of Foster & Whitney, F. S. Geologists, Part I. H. Ex. D. No. 69, pp. 1-224 and 12 Plates, First Session 31st Congress; S. Ex. D. No. 2, Vol. 2, p. 147, Second Session 31st Congress; Part II S. Ex. D. No. 4, Vol. 3, p. 3, Special Session 32d Congress.
The work of the Geological Survey was interrupted by the death of D. Houghton while actively engaged in explorations. See life of Douglas Houghton, by A. Bradish, which also contains a previously unpublished section, etc.

1846. Report from Geological Department by S. W. Higgins, principal assistant.
J. D. No. 12, 22 pp.
Report of the joint committee relative to the Geological Survey.
J. D. No. 15, 8 pages.

[4]p. 125 of the Fourth Annual Report above cited.

[5]Vol. VI—Studien des Göttingenschen Vereins Bergmännischen Freunde, Parts I and II. July 18, 1852; "Die Mineral Regionen der obern Halbinsel. Michigan's (N. A.) am Lake Superior und die Isle Royal," by Fr. C. L. Koch.

[6]Voyage au Lac Superior,—-par M. L. R. Rivot, Extrait des Annales des Mines, tome VII, p. 173, Paris, Victor Delmont, publisher, 1855.

[7]1861. First biennial report of the progress of the G. S. of M. Embracing observations on the Geology. Zoology and Botany of the Lower Peninsula. Made to the Governor. December 31. 1860.'

[8]Issued and reissued in various shapes and the standard material for geographers, between 1864 and 1873. At the latter date, they were issued in a separate book entitled, "Michigan" being condensed Popular Sketches of the Topography, Climate and Geology of the State. 800, pp. 121, 8 lithographic and four colored charts.

[9]See report on Huron County, pp. 14 to 23, pp. 252 to 294; also bibliographies in U. S. Geological Survey Bulletin. No. 80.

[10]Outlines of a Proposed Final Report of the Survey of the State of Michigan, to be made in pursuance of an Act, approved March 26, 1869.

1871. Report of the progress of the S. G. S. of M., pamphlet pp. 1-64.

1873. Vol. 1. Upper Peninsula, 1869-1873. Accompanied by an Atlas of maps. Edition 2,000.
Part I. Iron Bearing Rocks (Economic), T. B. Brooks. Of this an extra edition of 500 with thirteen accompanying atlas plates was issued.
Part II. Copper Bearing Rocks, Raphael Pumpelly (Plates 14, 14a, 15-23 of the atlas accompanying; Chapters IV, VII, VIII are by A. R. Marvine).
Part III. Palæozoic Rocks, Dr. C. Rominger. (Plate 24 of the atlas accompanies. There was an extra edition of 500 dated 1872, without map or index, differing slightly in title page, introduction and paging).
Vol. II. Upper Peninsula, 1869-1878, appendices to Part I, Vol. I. A. Lithology by A. A. Julien, B. Lithology by T. B. Brooks and A. A. Julien, C. Lithology by Charles E. Wright, D. Ore deposits, E. Lithology (Notes by D. Houghton). F. Iron ore dock(by Jacob Houghton and Chas. H. Palmer, with Plate XX). G. Census statistics (1870), H. Magnetic Analyses (by F. B. Jenney), I. Mining laws (by C. D. Lawton), J. Metallurgical qualities by H. B. Tuttle. K. Contortions of Laminae (by T. B. Brooks).

[11]H. Credner. See his geology and papers in various German geological Journals, abstracted in Monograph 46 of the U. S. G. S.

[12]E. g. N. H. Winchell in the Geological Survey Reports of Minnesota, McFarlane and Coleman and others in those of Canada; Brooks, Wright Irving, VanHise, Grant and others in those of Wisconsin, beside the U. S. Geological Survey Reports below referred to.

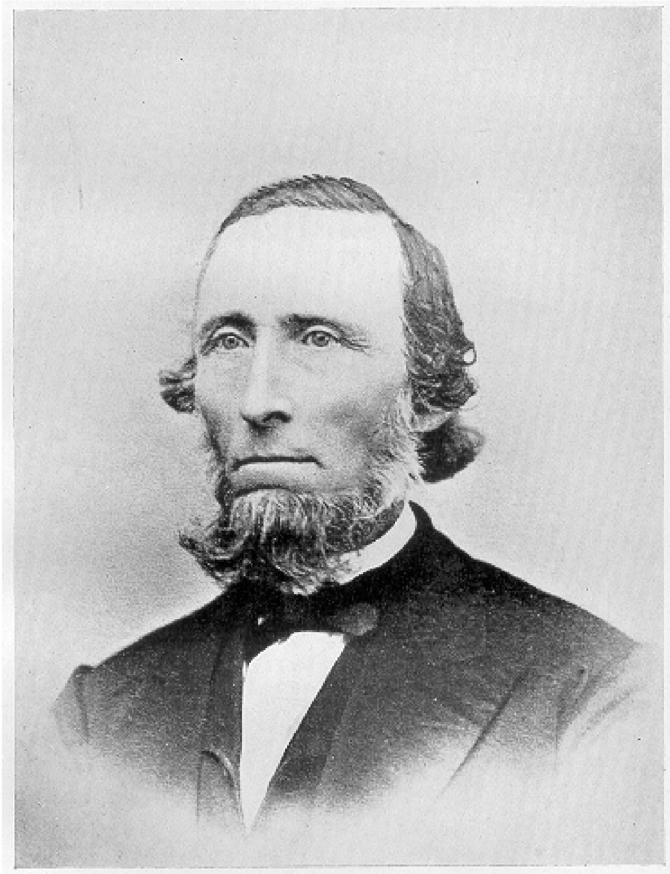
[13]See also papers by H. C. Hahn in the Berg-und-Huettenmaennische Zeitung, 1866, and the U. S. Geological Survey Water Supply paper, No. 31.
In bulletin No. 177 of the U. S. Geological Survey is given a full catalogue and index of the publications of the U. S. Geological Survey pertaining to Michigan, from 1880 to 1901 Monographs V, on the Copper Bearing Rocks ; XIX on the Gogebic District; XXVIII on the Marquette District; XXXVI on the Crystal Falls District; XLVI on the Menominee District; Bulletins 23, on the Keeweenaw Fault; 62 on the Greenstone Schist Areas Water Supply Papers Nos. 30 and 31 are wholly or largely devoted to Michigan.
The more recent publications of the State's Survey are described in circulars issued by them.

ABRAM SAGER, A. M., M. D.

Abram Sager was born at Bethlehem, Albany county, New York, December 22, 1810. In 1831 he was graduated from the Rensselaer Polytechnic Institute at Troy, New York, in which he had spent two years as pupil and instructor. While at this institution he was under the instruction of Professors Torrey and Eaton, men of note in the fields of botany and zoology. Their influence and guidance did much to direct his attention to these subjects. It may be stated that on the death of Professor Eaton, Dr. Sager was tendered the presidency of the Rensselaer Polytechnicum, but found it necessary to decline. Later, Dr. Sager continued his studies at Albany and at New Haven, Connecticut. At the latter place his work was done under the supervision of Professors Marsh and Ives, names well known to American science. He graduated in medicine at Castleton, Vermont, in 1835. After graduating in medicine Dr. Sager came to Detroit and engaged in general practice. In February, 1837, Governor Mason approved an act for the organization of a geological survey of the State of Michigan. It provided for a geological, zoological, botanical, and topographical survey. Under this act Dr. Sager was placed in charge of the Botanical and Zoological Departments. The second annual report of this survey contains a paper entitled, "A Systematic Catalogue of the Animals of the State, so far as Observed," by Dr. Sager.

In 1842 Dr. Sager assumed the duties of Professor of Zoology and Botany in the University of Michigan, and he continued in this chair until 1850, when, upon the organization of the Medical Department, Dr. Sager's work was transferred to the new department. The positions which he held in the State University may be summarized as follows: He was professor of Zoology and Botany, from 1842 to 1850; professor of Obstetrics, Diseases of Women and Children, and professor of Botany and Zoology, from 1850 to 1854; professor of Obstetrics, Physiology, Botany and Zoology, from 1854 to 1855; professor of Obstetrics and Physiology, from 1855 to 1860; professor of Obstetrics and Diseases of Women and Children, from 1860 to 1875. He prepared and presented to the University a herbarium containing about 1,200 species and 12,000 specimens. He collected and prepared many zoological preparations, and these constituted the nucleus of the present University Museum. He also prepared many specimens illustrating Comparative Neurology, Embryology and Craniology. In addition to the above he made and presented to the University a large collection of parasites found in man and other vertebrates and these are still to be found in the Pathological Museum.

While in general practice in Detroit he published an article on American Amphibia, which was translated and republished in German. In this article the author treats of the generic value of the arrangement and location of teeth in amphibia and describes more fully certain American salamanders, noting several new species. He also reported several zoological papers which are to be found in the proceedings of the Academy of Natural Sciences of Philadelphia. His strictly medical contributions are not numerous, but are of considerable value, and they are worthy of reading and of emulation on account of their conciseness, clearness and purity of diction.



DR. ABRAM SAGER.

Dr. Sager was a member of the American Association for the Advancement of Science, of the Academy of Natural Sciences of Philadelphia, of the Academy of Sciences of New Orleans, of the Academy of Sciences of Chicago. He was one of the first of the Michigan physicians to become a member of the American Medical Association; he was a member of the New York State Medical Society; of the Michigan State Medical Society, and of the Obstetrical Society of Philadelphia. His modesty and retiring disposition were incompatible with his becoming a prominent factor in any of the societies in which he was a member. It is said that when present at any such gathering, he was usually found occupying an inconspicuous place in the rear of the room, few members being aware of his presence.

In 1875 he obtained leave of absence from his university duties and spent the winter in Florida and South Carolina, returning in the spring temporarily relieved from his physical disability and looking forward to several years of active labor. These hopes were, however, not realized, and in 1874, on account of his illness, he found it necessary to lay aside the harness which he had worn so long, giving up all attempts at teaching.

The Regents conferred upon him the title of emeritus professor, and he remained as Dean of the Medical Faculty until June, 1875, when he felt obliged to sever all connection with the University. He developed Bright's disease from which he died August 6, 1877.

One of his colleagues (Dr. Breakey) thus speaks of Dr. Sager:

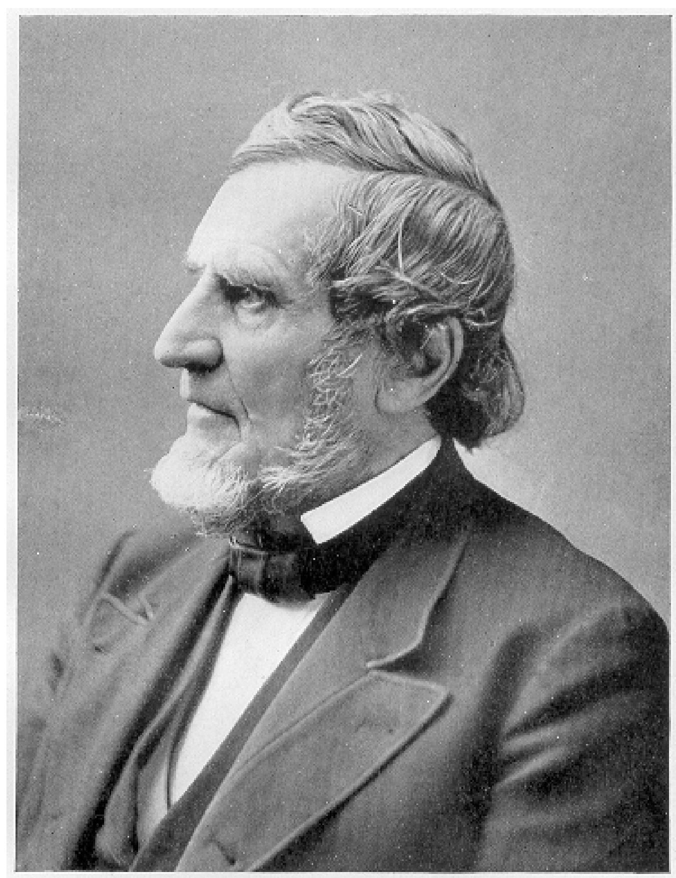
"His life teaches us that the success and fame most desired and enduring are achieved by straightforward, honest means, and by persistent effort; that devotion to truth, to scientific research, to the development of rational medicine without pretentiousness, without quackish art, with fidelity to obligations, brings its rewards in the esteem and commendation of professional brethren, the confidence and honor of the public, and the gratitude of patients." V. C. V.

CORYDON L. FORD, M, D., LL. D.

Dr. Ford was born of good Puritan stock in Greene county, New York, August 29, 1813. His father was a farmer, but infantile paralysis of one of his lower limbs rendered the youth unfit for the severe manual labor of the agricultural pioneer, and gave him more time for study. At the early age of seventeen he began his life-work of giving instruction to others. As a schoolmaster, he very soon developed that clearness and terseness of statement, enthusiasm in his work, and close sympathy with his students, which afterwards made his lectures veritable revelations to the man who attended them in search for knowledge. A good foundation for professional studies was laid at the Canandaigua Academy, and in 1842 the degree of Doctor of Medicine was earned at the Geneva Medical College. Dr. James Webster, then professor of Anatomy at Geneva, was noted for his skill in dissecting, his success in demonstrating, and his fluency in lecturing. Of this able teacher young Ford became, during his course of study, the favorite pupil; and on the day of his graduation he was appointed demonstrator of Anatomy. In 1846, Flint, Hamilton, White, Webster and Ford, all names now memorable in the history of medical education in this country, established the Medical College at Buffalo. In 1854 Dr. Ford was called to the professorship of Anatomy in the University of Michigan, and here he labored continuously for forty years. From 1854 to 1886, he gave a second course of lectures, and sometimes a third, in other schools during the spring or summer months: At Castleton, Vermont, until 1861; in the Berkshire Medical College, at Pittsfield, Massachusetts, from 1860 to 1867; in Bowdoin College, from 1864 to 1870; and in Long Island College Hospital, Brooklyn, from 1868 to 1886. By thus giving two or more courses in different schools in the same year, Dr. Ford finished his one hundred and ninth course of lectures in Anatomy the day before he was stricken by death.

Probably no other professor, certainly no other professor in a medical school in this country, has given instruction to so many students, and it can also be said that no other teacher has won more of the respect, confidence, and love of his pupils. Thousands have sat at his feet, have seen him make the dry bones objects of interest, convert the shriveled muscles into volumes of information, and cause the dead to teach the living how to heal the sick.

Dr. Ford gave all his time and energy to teaching, and as a consequence contributed but little to the literature of his chosen science. However, he made extensive notes, and it is likely that among these there may be found records of valuable scientific facts. As a great oral teacher, a class not numerous in these days when hand-books, text-books and compends are produced so abundantly, he will be remembered and revered by his students. In recognition of the great service he rendered in building up the Medical Department of Michigan University, Dr. Ford was honored with the degree of LL. D. in 1881. It is not generally known, but it is true, that Dr. Ford was a surgeon of ability and of no little skill, as well as an anatomist. His perfect knowledge of the relations of the different tissues in every region of the body made his advice and assistance to the general practitioner, who, when called upon to do a surgical operation often finds his knowledge of anatomy less extensive than he had supposed, of the greatest service, and in western New York he was often called, not only to advise and assist, but to do the operation. He ligated some of the larger arteries a number of times, reduced fractures and made amputations.



DR. CORYDON L. FORD.

After coming to Ann Arbor Dr. Ford was not called upon to do much surgery until Dr. Gunn went to the front as an army surgeon, and during this time Dr. Ford did all the operations at the surgical clinic. The late Dr. Skene, of Brooklyn, New York, who was a student in the University of Michigan at that time, has testified to the fact that Dr. Ford handled the knife with equal judgment and skill as an anatomist and as a surgeon. Dr. Ford died at his residence in Ann Arbor April 14, 1894, of cerebral apoplexy. He had given his last lecture of his fortieth year of service in the Medical Department of the University only two days before he passed away.

V. C. V.

STUDIES IN DENITRIFICATION.

S. F. EDWARDS.

Denitrification is, as the term implies, a reducing process in which the nitrogen of the soil is eliminated in one form or another by the breaking down of the nitrate or complex nitrogenous compounds, thereby becoming lost to plant growth. It is still to a great degree an open question in what form the nitrogen is lost, whether as oxides of nitrogen, free nitrogen or free ammonia, or in more than one of these forms.

The denitrification phenomenon was first noticed in cultivated soil in 1862 by Goppelsröeder, and for a long time it was regarded as a purely chemical process. The first reference to the agency of bacteria in the changes produced was made in 1875 by C. Meusel, and the earliest pure cultures of such micro-organisms were made in 1882 by U. Gayon and G. Dupetit. In 1886 W. Heraeus made known several species of the denitrification class and two years later Percy Frankland and R. Warington found a large percentage of soil bacteria capable of reducing nitrates to nitrites although they do not state whether their cultures possess the power of further reduction.

In later years scores of workers have entered the field, and, working upon different phases of the subject have secured some very valuable results.

The object of our investigation was to contribute something toward a solution of the problem by a detailed study of the denitrifying properties of three germs found commonly at a depth of two to six inches in different soils upon the farm at Michigan Agricultural College, viz.: Bacillus subtilis, B. megaterium, and B. mycoides.

A brief outline of the investigation pursued follows:

1. Action upon nitrate.
2. Action upon nitrite.
3. Action upon ammonium salt.
4. Effect of the presence of organic matter.
5. Influence of abundant oxygen supply.

1. Action upon Nitrate.

As has been stated, in 1888 Franklin and Warrington found a large number of soil bacteria capable of reducing nitrate to nitrite, but leave no record of further products. In our work an endeavor was made to determine quantitatively the reduction of nitrate to nitrite, and whether any further products resulted. The culture solution used contained, besides the potassium nitrate which formed its basis, the other elements necessary for plant growth in various salts, and a small amount of organic matter in the form of peptone.

Seventy-five c. cm. Erlenmeyer flasks, plugged and sterilized in dry heat, received twenty-five c. cm. of the culture solution and were sterilized intermittently in moist heat. The inoculations were made with .5 c. cm. of cultures of the germs in a mineral solution containing a minimum of nitrate or organic matter, some of the flasks being retained uninoculated for controls. The cultures were kept in a darkened room at an average temperature of twenty-five degrees C. In all the work with mineral solutions bouillon tubes were inoculated with small portions from the culture and control flasks to verify the vitality of the cultures and sterility of the controls. Determinations of nitrite and free ammonia were made at the time of inoculation and at intervals thereafter.

TABLE I.

Nitrites expressed in grams per litre of N_2O_3.

Ammonia expressed in grams per litre of NH_3.

	At inoculation.		At two days.		At seven days.		At sixty days.	
	N_2O_3	NH_3	N_2O_3	NH_3	N_2O_3	NH_3	N_2O_3	NH_3
B. subtilis	None	None	None	.0099	.1433	.016	.264	.0064
B. megaterium	None	None	None	trace	.2576	.0224	.4198	.0064
B. mycoides	None	None	.033	.016	.033	.0224	.0882	.0128
Uninoculated Control	None	None	None	None	None	None	None	None

The theoretical amount of N_2O_3 per litre of the original culture solution from KNO_3 equals 3.762 grams. The amount of NH_3 per litre from the KNO_3 of the culture solution equals .841 grams. The results show a steady increase in the amount of nitrite as the cultures become older. The amount of ammonia shows a decrease at the time of the last test, a phenomenon which may be accounted for by the gradual degradation of the ammonia compounds formed, and the liberation of free nitrogen, a question which at present remains unsettled.

A. Do the Nitrites and Free Ammonia Result from the Breaking Down of the Nitrate or the Peptone?

Upon examination of the results of Table I., the question arose whether at least a portion of the nitrite and free ammonia might not be products of the analytical destruction of the peptone. To settle the point, a solution was prepared which was identical with the previous one with the exception that no nitrate was used, and the cultures were handled in exactly the same manner. The results are shown in Table II.

TABLE II.

Nitrites expressed in grams per litre of N_2O_3.

Ammonia expressed in grams per litre of NH_3.

	At inoculation.		At two days.		At seven days.		At sixty days.	
	N_2O_3	NH_3	N_2O_3	NH_3	N_2O_3	NH_3	N_2O_3	NH_3
B. subtilis	None	None	None	.0121	None	.0194	Trace	.0048
B. megaterium	None	None	None	None	None	.0242	Trace	.0291
B. mycoides	None	None	None	.0048	None	.0291	.011	.0194
Uninoculated Control	None	None	None	None	None	None	Trace	None

From a comparison of the tables the fact becomes evident that most of the ammonia in the nitrate cultures results from the degradation of the peptone. No reaction for nitrites was obtained until the cultures were old and then only a trace. Whether this was due to spontaneous chemical changes is a question. The fact that the control, which remained sterile, showed a trace of nitrite would lead one to suspect that such was the case. The work was duplicated in order to verify it and the same results were obtained. These results agree with Maassen (Cent, f. Bakt. 1902 II No. 5. S. 152) who grew 109 common bacterial species in a mineral solution containing peptone, and who says in stating his results; "Considerable ammonia was also produced on account of the vigorous peptonization."

2. Do the Micro-Organisms Have a Reducing Action upon Nitrites?

To determine whether the micro-organisms were capable of reducing nitrites a nutrient mineral solution having nitrite for its basis was prepared, and cultures were made and handled in the same manner as in the previous work. Tests were made at various intervals, but in only one case, B. mycoides, was any decrease in nitrates apparent.

3. Action of the Organisms upon Ammonium Salt.

Cultures were made in a nutrient mineral solution having for its basis ammonium sulphate, and Nessler determinations were made at intervals to discover, if any, the decrease in the amount of ammonia. Duplicate tests were made at different periods, the results of which corresponded. At no time was any change observed in the ammonia content, showing that these bacteria have not the power of reducing ammonium sulphate, and furthermore that this salt prevented the production of ammonia from the peptone which was present in the solution.

4. The Effect of the Presence of Organic Matter upon Denitrification.

Künneman, a German investigator, in 1898, in experiments carried on with a micro-organism which he had isolated from horse dung, found that the amount of denitrification decreases as the amount of organic matter increases, which observation was also made by Matz and Wagner, who stated that as "humification" proceeds, the power of destroying nitrate decreases. On the other hand, Pfeiffer states that denitrification can take place only in the presence of straw, feces or vegetable tissue which act as food substance for the denitrifying organisms. Stutzer and Maul isolated two micro-organisms which gave very marked nitrate reducing power when grown in a solution containing a small amount of organic matter. Maassen states that in a strictly inorganic solution he obtained very little reduction of nitrate by common bacteria. In our studies along this line five solutions were used, differing only in the nature of the material furnishing the combined nitrogen to be acted upon, the basis of the different solutions being as follows: Ammonium nitrate and Potassium nitrate, Asparagin, Potassium nitrite, and Potassium nitrate and nitrite combined in equal amounts. The other elements necessary to plant growth were added in various salts, but none of the solutions excepting the asparagin contained any organic matter. The cultures were tested at the end of forty-five days for the reduction products. In only one of the solutions, Asparagin, were satisfactory results obtained. There was practically no formation of nitrite or ammonia, and upon plating in ordinary gelatine it was found that while the microorganisms still possessed vitality, there was no vigor of growth. The cultures in Asparagin developed vigorously, and there was a very marked production of ammonia, the controls yielding no reaction for ammonia. A comparison of the results obtained in these strictly mineral solutions with those obtained from solutions containing a small amount of organic matter, leads to the conclusion that the presence of the latter is imperative in order to secure abundant denitrification. What would be the effect of large amounts of organic matter is still an unsettled question.

5. The Effect Upon Denitrification of an Abundant Supply of Air.

In a study of this question, Deherain in 1897. upon growing microorganisms from straw and the solid excrement of animals, found that the reduction was much more rapid in closed than in open flasks, although he does not state whether the conditions were strictly anaerobic. Maassen states, that while denitrification is not inhibited by anaerobic conditions, it proceeds best in a limited supply of air. Pfeiffer in 1897, found that in a culture of B. denitrificans the admitting of pure air did not lessen the amount of denitrification. In 1898, Ampola and Ulpiana isolated from soil a micro-organism which grew well both in the presence and absence of air.

In our work, one purpose was to so construct a piece of apparatus that air might be freely drawn through the culture, and yet that the danger of contaminations might be eliminated. Five seventy-five c. cm. Erlenmeyer flasks were tightly fitted with two-hole rubber stoppers and connected with U tubes, one arm of which extended to the bottom of the flasks. Two each of the end flasks contained normal-fifth sulphuric acid, the middle one holding the culture solution. Thus when air was drawn through, the apparatus, the sulphuric acid in the first two flasks would absorb any ammonia from the air passing through, as well as any microorganisms which might be drawn in with the current. The other two acid flasks were to catch any ammonia that might be given off from the culture drawn over upon äeration.

Furthermore, one series each of cultures sealed, and simply plugged with cotton wool were used, uninoculated controls being used in each case; also cultures and controls were placed in an atmosphere entirely devoid of oxygen. The culture solution was prepared similarly to the previous ones of mineral salts and containing a small amount of peptone.

After eleven days growth determinations were made of nitrites and free ammonia in the cultures and controls. The acid flasks of the aeration apparatus were titrated against normal-fifth sodium hydroxide, but showed no indication of absorption of ammonia.

TABLE V.

Nitrites expressed in grams per litre N_2O_3.

Ammonia expressed in grams per litre NH_3.

	N_2O_3	NH_3
Cultures in Absence of Oxygen:		
B. subtilis	None	None
B. megaterium	Trace	Trace
B. mycoides	Trace	.0080
Uninoculated Control	None	None
Cultures Sealed:		
B. subtilis	.0330	.0064
B. megaterium	.0440	.0080
B. mycoides	None	.0240
Uninoculated Control	None	None
Cultures Unsealed:		
B. subtilis	.0440	.0128
B. megaterium	.0495	.0244
B. mycoides	.0551	.0160
Uninoculated Control	None	None
Cultures thoroughly aërated:		
B. subtilis	.0826	.0192
B. megaterium	.1101	.0160
B. mycoides	.0551	.0240
Uninoculated Control	None	Trace

A litre sterile culture solution contains .1264 grams N_2O_3.
A litre sterile culture solution contains .028 grams NH_3.

The results show that the reduction depends almost entirely upon the presence of at least a small amount of oxygen, and that, except in the case of B. mycoides, a greater supply of air induces a greater amount of reduction.

CONCLUSIONS.

1. The three micro-organisms under investigation have the power of acting upon nitrates to reduce them to simpler substances, nitrites, free ammonia, and probably free nitrogen.

2. The nitrites present in a culture solution having nitrate for its basis result entirely from the nitrate.

3. A portion of the ammonia usually found in cultures in nitrate solutions containing organic matter, results from the decomposition of this latter material.

4. For a vigorous development and activity of these micro-organisms, the presence of at least a trace of organic matter is essential.

5. Not all bacteria having the power of acting upon nitrates are also capable of exerting a reducing action upon nitrites.

6. The bacteria studied can not reduce ammonium sulphate; furthermore, the ammonium sulphate checks the production of free ammonia from the peptone in the solution.

7. These micro-organisms act more vigorously in the presence of an abundant supply of oxygen.

PRESENT METHODS OF TEACHING SOILS.

PROF. J. A. JEFFERY, AGRICULTURAL COLLEGE.

The present methods of soil study are somewhat evolutionary. There are few institutions that are offering more than a very simple course in soil work. In most of our colleges the work is given by men whose training has been along other lines, but who occupy the position of agriculturist, who feel the importance of a larger knowledge of the nature and principles of soils, and who with the time and facilities at hand are doing what they can in this direction.

The University of Wisconsin was the pioneer in the development of a strictly soil course. Ohio followed with a less extensive course and Illinois is building up such a course. M. A. C. is doing a similar work and South Dakota is doing a very creditable line of work, while the letters of inquiry that come to us from east and west for information as to methods, show how rapidly the interest is growing—Connecticut, Iowa and Oregon within the past few months. Wisconsin is doubtless best equipped for the work. Illinois, Ohio and Indiana have splendid facilities in the way of quarters and are rapidly building up their other equipment. Iowa has a magnificent building in sight and North Dakota is transforming a part of its boys' dormitory into a soils laboratory.

Where room and equipment are provided, a serious difficulty is encountered in securing trained men to take up the work of instruction and direction. In some cases men are put in charge who have to build up their departments and themselves at the same time. In other cases funds for the development of such a course come slowly.

Scarcely any two institutions offer like courses or follow the same methods of instruction, and yet, all pattern to a greater or less extent after the methods developed by King of Wisconsin and in addition give some attention to methods of soil investigation practiced at Washington and by Hilgard of California.

The time of taking up the work in soils and the time given to the work, are not the same in all institutions. At Wisconsin no work in agriculture is given prior to the junior year. At that time if the student elects soils as his major, that work is followed by him during the junior and senior years. If soils is made a minor, the time devoted to soils is much less depending upon the other elections made. At Ohio one term is given in the junior year, while agronomy, which includes one term of soils, may be elected for the senior year. At Illinois soils is a required study during the first semester of the junior year, while electives are offered during the senior year. It will be observed that in the three cases just named, no work in soils is done prior to the junior year and is thus taken after two years of university training.

It is the plan at M. A. C. to give some work relating to agriculture in every term of the freshmen and sophomore years, with the privilege of electing agricultural work during a part at least of the junior and senior years. The object of this arrangement is that many of the students coming to us remain only through one or two years. Such students going back to the farm take with them knowledge relative to agriculture that shall increase their capacity as producers.

The first work in soils is given during the last four weeks of the winter term. This work consists of lectures upon the history and distribution of the principal types of soil. In this work it is sought by simple talks to show that all arable soils are derived largely from rocks, to show what agencies—heat, moisture, air, plant and animal life, etc., are operative in bringing about these changes, and that the value of any soil will depend very largely upon the nature of the rock from which it is formed.

A soil may occupy the position—practically—in which it was formed. Such soils are found in the limestone area including a part of southwestern Wisconsin, and in the sandstone area lying to the north of it. Such soils are called residuary soils—soils of immediate origin. The location of the principal areas of this type of soil is indicated.

The formation of the drift, or till soils, volcanic soils, alluvial soils, wind blown soils, etc., are taken up and their characteristics, qualities, and possibilities discussed. As in the former case the location of these soils is indicated. The peculiarities of the soils of the arid regions and of prairie soils, and some at least of the causes thereof, are discussed.

As far as possible samples of the several soils are shown to the class and the talks are illustrated by lantern slides. To this end we are gathering samples of soils from different sections of the United States, and we have one sample from Burmah, India. We are also adding to our collection of lantern slides. In all this we show that many of the agencies active in building up soils may become active, under proper conditions, in wasting the soil. We show how nature, left to herself, holds and improves her soils, and so far as possible, we show where we may imitate nature both in conserving soils and in obtaining the largest returns from them.

We explain how valuable soils are injured or destroyed by the carelessness or ignorance, or both, of the husbandman, giving some estimates of the extent to which lands have been injured or destroyed and calling attention to some of the cases in which large areas have been abandoned because of their impoverishment. We call attention, too, to the manner in which soils affect the type of manhood, apparently, and the history of nations as well.

We find that almost without exception, these simple talks arouse a good deal of interest in the student. The soil becomes to him a thing of life, so to speak, and he seems to acquire a new respect for it.

This work is given in the form of lectures because there is no satisfactory text-book on the subject to be had. Students are required to make careful notes.

During the spring term of the freshmen year we give attention to soils from the agricultural standpoint.

We discuss the chemical composition of soils and estimate, from analyses given, the amounts of the several plant foods in the first foot and in the first four feet of soil, and then from the computed quantities of material removed annually by crops, estimate the possibilities in our soil of crop growing. The fact of the wearing out of our soils and their unproductiveness are compared with our theories, and explanation sought for the apparent conflict.

Attention is given to the biology of the soil which concerns bacteria and mold life found therein and the functions of these in transforming the store of nitrogen in the soil and probably also the mineral foods into soluble form for the use of the higher plants.

Soil moisture, soil air, and soil temperature are taken up in order and studied under the general heads:

(1.) Importance to crops and the changes above referred to.
(2.) The ideal conditions, and
(3.) The means by which the farmer may modify or control them.

The third head naturally leads to the study of farm implements and the art of their construction and use and also to the study of the theory and practice of farm drainage.

Fortunately we now have a few very good texts upon soils as we take them up during this term which we are able to supplement with laboratory and field practice.

A portion of the sophomore fall term is given to the study in the laboratory, of air movements and water movements in the soil, to the determination of the moisture content of soils and to the mechanical separation of a sample of soil into its sand, silt, clay, and organic constituents.

The work thus far outlined is required of all agricultural students. Any further work he may take is made up of what it may appear paradoxical to call required electives. In the winter term of the junior year, the student elects between horticulture and agriculture. Should he elect agriculture, he plans to specialize in soils and crops or live stock or dairying. If his election be soils or soils and crops, then during the spring term of the junior year, he devotes ten hours per week to carrying out some practical experiment planned during the winter term, along some line of soil or crop work, as for example, to determine the amount of moisture taken from soils by a crop of weeds or the effect of manures upon soil temperature.

Eleven weeks of the fall term of the senior year are devoted to laboratory studies of soils. Four to six samples of soils are given to the student of which he is to determine the specific gravity, apparent specific gravity, least pore space, waterholding power—capillary and hygroscopic, and the effective size of soil grain with the theory of the methods, to classify and compare the several values and discover, if possible, any existing relations.

The electrical method and its theory for determining the soluble salts in soils is studied and the apparatus operated.

During the winter term of twelve weeks, each student carries on some line of investigation, giving ten hours per week to the work. This work is written up in the form of a thesis.

In the spring term soil thermometry, evaporimitry, and the natural pore space of soil is studied and if any time is left some problems in soil mathematics, such as the estimation of the total surface of unit volume of soil and some of the theoretical values and actual values compared.

While the work of the senior year possesses no small value for the young man returning to the farm, it is planned especially with a view to better equipping him to take up the work of instruction or investigation. The demand for young men for these lines of work at the present time is very great.

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