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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 Fourth 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,
Secretary of the Michigan Academy of Science.

Ann Arbor, Mich., Dec. 18, 1903.

THE VALUE OF SCIENTIFIC RESEARCH TO THE STATE.

BY VICTOR C. VAUGHAN.

Members of the Michigan Academy of Science:—Please permit me to thank you in the first place for the honor which you have done me in making me President for this year of the Academy. Every man desires the good will of his neighbors, and so far as the scientific man is concerned, honors of this kind make up the larger part of the recompense which he receives for his toil. It is especially pleasant to be honored at home, by those who best know one. I thoroughly appreciate the fact that my predecessors in this position have made it an honorable one, and I feel that you have placed me in good company, and I only hope that I may bear myself worthily.

I have decided to say a few words concerning the value of scientific research to the state. In order that I may not use words loosely, and that I may plainly indicate my meaning, I will attempt a short analysis of this subject. In the first place, it may very properly be asked, what constitutes scientific research. I apprehend by these terms the acquisition of new facts. The man who adds to the sum total of knowledge possessed by the race may be said to be an original investigator. The extent and the value of his contribution may be small or great. This is a matter of secondary importance. The man who pushes out and ascertains and establishes a fact not hitherto demonstrated deserves a place among research students. The history of mankind shows that our race since its earliest beginnings has always been hampered by ignorance and its constant accompaniments prejudice and superstition. Civilization has progressed by the slow and laborious process of extending farther and farther the limits of human knowledge. In every century there have been a few whose labors have in this way contributed to the advancement of man from the savage to the civilized state. During some periods in the history of the world the number of those engaged in acquiring knowledge and advancing the bounds of civilization have been extremely small. These are known as the dark ages of the world; when the bulk of mankind has apparently receded rather than progressed. However, a close analysis of the history of any age will show that even during the periods of the most dense intellectual darkness there have always been some who have given their lives to the advancement of knowledge. For the most part these have been men of lowly position, whose work at the time attracted but little or no attention. Occasionally they have been men of prominence, and the ideas advanced by them have been rejected by their contemporaries, and in some instances they have met with personal persecutions. These are the men who make up the list of martyrs which science has furnished the world. There have been occasional periods of great brilliancy when scientific investigation has been popular and has met with encouragement by those occupying high positions. Fortunately for us, we live in one of these

brilliant periods, when scientific investigation is popular, when its benefits are felt and appreciated by many.

I have already said that the value and extent of additional knowledge attained by the labors of a given man are variable quantities. As a rule the contributions of any one individual taken by themselves would be of but little value, but when added to the sum total they mar be of the greatest importance. The direct application that can be made of a scientific discovery is not a correct measure of its value. It often happens that a certain investigation leads to the discovery of a fact which at the time appears to be wholly without value, but the advances made in subsequent years may convert the rough pebble dug from the mine, possibly centuries before, into a most valuable jewel. We are therefore correct when we that science should be pursued for its own sake and without any reference to its future utility. Discovery must always precede use; science must live and labor before art can exist; pure science must always precede the application of scientific knowledge.

A scientific man is one who adds something to the sum total of knowledge possessed by his race. Scientific research is the process by means of which these discoveries are accomplished. The range of science is unlimited; it embraces everything existent; it deals with both matter and energy; it may concern itself with the infinitesimally small, or it may lead to investigations that carry ones thoughts to distant parts of the universe. Some people say that science is materialistic and the scientist a materialist. Such assertions are made by those who know not whereof they speak. More than anyone else does the scientist realize that there are other things in the universe than matter. He knows that energy is real as substance. He is aware of the fact that light, heat, motion, electricity, and other forms of energy are as real as the matter in which or through which they manifest themselves. In fact, it is the scientist who measures energy, and it is by means of his discoveries that the wonderful applications of electricity and other forms of energy have been made to the benefit of the race.

Having endeavored to explain what I mean by scientific research, I now desire to say a few words concerning its value to the state. I shall not attempt to measure the value of scientific discoveries in dollars and cents, because I apprehend that there are other values which the mass of mankind can appreciate, and which many at least are wise enough to prefer to wealth. I think that all will agree with me when I state that a scientific discovery which reduces sickness and death and gives to mankind longer life and greater happiness is of value to the state. A discovery which lessens crime and empties are penal institutions is by no means without value. A discovery which gives us grander conceptions of the universe, which awakens and develops lofty ideals and leads to strength of character and purity of life is one, the value of which to mankind cannot be placed up on a financial basis.

A few illustrations of the good that has come to man from certain scientific discoveries may not be amiss. Of course I cannot go very deeply into the subject as I have neither the time nor the inclination to trespass upon your indulgence too greatly.

Primitive man as he wandered over the earth, more of a beast than a human being, saw many things undoubtedly which greatly surprised and in some instances terrified him. Probably nothing else had for him greater terror than the volcano, which his crude imagination and his superstitious theology believed to be the opening into regions occupied by demons and devils. If in pursuing his scarcely less savage game he came across fissures in the earth from which inflammable gasses issued, and if he saw these aflame,—as he probably did around the shores of the Caspian Sea,—great indeed must have been his horror. These strange phenomena were not explainable, and centuries passed before he had any conception of their true character. After a while he discovered coal and began to use it, but century after century passed before he thought of obtaining an inflammable gas from this substance. In 1726 one, Dr. Stephen Hales, made, so far as we know, the first attempt to submit coal to distillation and to obtain and utilize the gases that might be evolved by this process. In a communication to the Philosophical Society he tells of his experiments, which apparently were made with great scientific accuracy, although on a very small scale. He not only distilled the coal, collected the gases, but he determined the amount of gas that could in this way be obtained from a given quantity of coal, and he states that from 158 grains of coal he obtained 180 grains of an inflammable gas. Thirteen years later, or in 1739, the Reverend John Clayton in a contribution to the Royal Philosophical Society detailed experiments of a similar kind in which he distilled the coal and collected the gases in bladders. From this time on for many years the formation of an inflammable gas by the distillation of small quantities of coal was looked upon as an interesting laboratory experiment, but of no special value, and it was not until the year 1792 that Robert Murdoch made his first attempts to obtain coal gas in large quantities and utilize it for illuminating purposes. From that time up to the present, every decade has seen some improvement in the preparation or utilization of illuminating gas. The value of this discovery to the world can hardly be summed up in a few words. In the first place, morally it has been more effective than many sermons. Before our cities were lighted at night even the most frequented streets were often the scenes of all kinds of crimes, among which murder was sometimes included. Street illumination has done more in policing cities than could have been accomplished by an army of men. As the dark corners have been lighted up crime has disappeared or gradually receded into the still darker recesses. The value of the discovery and utilization of illuminating gas from an economic standpoint must amount to untold billions of dollars. It has enabled commerce to be carried on at night as well as by day. Illumination has permitted

continuous work in manufacturing establishments of many kinds; has given employment to thousands, and the world owes today a debt of gratitude to Hales, Clayton and others who in the early part of the eighteenth century were engaged in scientific research, probably without ever dreaming of the great benefit which their little experiments might subsequently confer upon humanity.

In 1849 a physician by the name of Pollender busied himself with studying microscopically the blood of certain animals both in health and in disease. He first made himself perfectly familiar with the appearance of normal blood, after which he began to observe the blood of man and animals while suffering from disease. In the course of these investigations he took the blood from a cow sick with anthrax and examined it under his microscope. He observed minute rod-like bodies which he had not found in the blood of healthy cows. He repeated this observation many times, carefully comparing the blood of sick animals with those of healthy ones. Finally he concluded that these little rod-like bodies observed in the blood of sick animals had something to do with the disease from which they suffered, and he presented to one of the journals of the time a short contribution upon this subject. His labors attracted but little attention and that little was for the most part in the form of ridicule. Some years later Davaine took up the same line of work and pushed it a little further. He confirmed Pollender's observation of the presence of the rod-like bodies in the blood of animals sick with anthrax, but closer study showed him that these organisms,—for such he believed them to be,—were not always present in the earlier stages of the disease. Next he ascertained that if he took the blood containing these rod-like bodies and injected it into a healthy animal the second animal developed anthrax, while blood which did not contain these organisms did not transmit the disease to other animals. This was an important step in advance. Occasionally there had been a physician who had claimed that certain diseases must be due to minute micro-organisms or germs, but no one had ever seen anything of this kind, because the demonstration of the existence of germs had to await the development of the compound microscope. After Davaine, his work was taken up by Pasteur and then by Koch and a host of others until it has developed into the great science of bacteriology. Now let us stop for a moment, look about us, and see something of the great benefits that have come to mankind from the researches of Pollender, Davaine, Pasteur, Koch, and others. Upon the discoveries made by these men the whole science of preventative medicine as it stands today has been built. As a result of these experiments the last fifty years has been freer from eipdemics than any other equal period in the history of the world. Every time we disinfect a room after a case of diphtheria or scarlet fever we are utilizing that knowledge, the first contribution to which was made by the modest physician Pollender in 1849. It was this discovery, and the science that has been built upon it, which enabled this nation in 1892 to arrest Asiatic Cholera in New York harbor and prevent its entrance and dissemination in this country. These discoveries have developed the various processes of disinfection now in vogue by means of which the spread of disease has been so greatly restricted. They have so changed methods of quarantine that the name now applied to the prevention of the introduction of disease into a community or a country is a misnomer. In the olden times quarantine meant forty days of detention, an even with this, disease was not always arrested, because the germs lingered in the hair or in the clothing during the period of quarantine and were subsequently carried ashore and disseminated. Now quarantine has a wholly different meaning. It means a few hours of detention with thorough disinfection, and when scientifically done it means the certain restriction of disease. We can hardly estimate the great benefit that this has been to commerce, and the greater benefits that are still likely to follow from less prolonged detention and more thorough disinfection. The science of bacteriology, founded upon the simple experiments mentioned above, has enabled mankind to practically stamp out certain of the infectious diseases. For instance, typhus fever, which once contributed largely to the mortality lists of every large city, now is known only in certain obscure and unclean parts of the world. The mortality in typhoid fever has been reduced from nearly thirty per cent to less than ten per cent, while at the same time the number of cases has been decreased in still greater proportion. Under the knowledge which we have gained by the study of the causal relation of bacteria to disease, and which had the small beginnings already referred to, even tuberculosis, the great white plague, is gradually diminishing in virulence, the number of cases is decreasing, the death rate is diminishing, and if man continues to apply the rules for its restriction which he has already devised, not more than a century or two at most will pass until this disease will be known no more. Twenty years ago there were wild hypotheses and vague conjectures concerning the causation of certain disease which greatly increased infantile mortality. Man looked for the cause of these diseases in the sun spots, he listened for it in the winds, he dug for it in the earth, he searched for it in the water, but bacteriological study has shown him that the great cause of cholera infantum and kindred diseases lies in milk which becomes poisonous on account of bacterial invasion and the elaboration of toxins. Already it is estimated that of children sick with this disease, thirty more out of every hundred are saved now than was formerly possible. In other words, the per cent of recoveries has been increased from fifty per cent to eighty per cent, and at the same time the number of cases of illness has been greatly reduces,—we cannot say just in what proportion. These are some of the advantages that have come to mankind from scientific research. Disease has been lessened, death has been delayed, health and happiness have multiplied. Are these not things of value to the state? Not only have all these things been accomplished, but possibly still greater good is to be found in the physical betterment of those who have not been ill.

This same science of bacteriology has enabled us not only to limit the spread of infectious diseases, but it has given us the most brilliant results ever attained in the cure of disease. It has largely robbed diphtheria of its horrors and has reduced the mortality from this disease from over fifty per cent to less than five per cent in cases in which antitoxin is used immediately on the appearance of the disease. This is a triumph in curative medicine which the most sanguine and visionary man of even ten years ago could scarcely have expected. The same science has given us a means of combating that rare but distressing disease known as hydrophobia, and of preventing the same. Who can say that the world has not benefited by the labors of the pioneers in bacteriology? Who can overestimate the discoveries of Pollender and Davaine, which to their contemporaries seemed to be at most of only trifling importance? Who can foretell the benefits that may come to mankind from what appears to be a trifling scientific discovery?

The bacteriologist has not confined his labors to the study of those microorganisms which cause disease, but he has gone farther and has shown that some of these minute forms of life which we call germs are capable of rendering great service to mankind. Only a few years ago it was believed by many scientists that the amount of combined nitrogen in the world is constantly decreasing, and that neither plants nor animals are capable of utilizing free nitrogen in the air. It was therefore supposed to be a necessary conclusion that life on this planet must cease as soon as all the combined nitrogen is used up. It was stated that the explosion of every ounce of gunpowder, whether the projectile which it carried struck a living object or not, carried death with it, inasmuch as it lessened the sum total of combined nitrogen in existence. The bacteriologist by his investigations has shown that this state of affairs is not so bad as was once believed. He has demonstrated that there are certain microorganisms growing on the roots of certain plants, and that by the combined action of the germ and the plant free nitrogen may be taken from the air and utilized in building up plant tissue or in other words, that it may be changed from the free to the combined form, and when thus changed it may subsequently be used for food by either plants or animals. This is what is known as the process or function of fixing nitrogen, and it depends upon the combined action between certain germs and leguminous plants. About twenty years ago it was quite conclusively shown that peas, beans, and other legumes when grown in a soil wholly free from nitrogen were capable of constructing nitrogenous compounds and building up nitrogenous plant tissue, while the only source of the nitrogen thus utilized was that existing free in the atmosphere. At first this view was believed to be founded upon faulty observations, but thorough experimentation has shown that the statement made above is a fact. Then men set about to ascertain the conditions under which plants, and especially leguminous plants are able to utilize the free nitrogen of the atmosphere. These experiments were conducted by skilled botanists in various parts of the world, and now after twenty years of these labors it can be positively stated that the manner in which leguminous plants convert nitrogen into compounds has been discovered. If the roots of a leguminous plant be studied they will be founded to be dotted with tiny nodules, which are known to the botanist as tubercles but which, however, have no relation to the pathological conditions known to the medical man under the same name. These tubercles or swellings on the roots of the pea vine vary markedly in size. They may be so small that they are barely discernible to the naked eye, and in some instances they have a diameter of one-sixth of an inch or more. Of course the existence of these nodules on the roots of leguminous plants had been long known, but their function was not understood. It was generally believed that their presence indicated a diseased condition, but it was found that the plants on the roots of which they developed most abundantly thrived most vigorously. I shall not attempt before this audience, in which there are many who know more about this subject than I do, to go into detail concerning the relation of these tubercles to the fixation of nitrogen by leguminous plants. Suffice it to say that experimentation has shown that these nodules do not form on the roots of plants grown in sterilized soils, and that under the same conditions such plants take up no nitrogen from the atmosphere. Next it was found that if leguminous seeds were planted in sterilized soil, devoid of nitrogenous food, and were water with an infusion of sterilized soil, they manifested two characteristic and peculiar stages of growth. At first the peas sprouted readily and grew vigorously for a very short time, when growth ceased. This period, which the botanist now designates as the stage of nitrogen hunger, was reached as soon as the plant had used up all the combined nitrogen in the seed. If at this stage some of the plants were watered only with sterilized earth infusions they did not recover, but continued to waste away and finally died, while those watered with non-sterilized soil infusions soon began to take on a vigorous growth, eventually developed into well nourished plants, and produced an abundant yield. Upon examining the roots of these two sets of plants it was found that those watered with sterilized soil infusions showed no tubercles or nodules, while those watered with non-sterilized soil infusions carried these tubercles. These experiments quite naturally suggested that the tubercles were formed by the agency of bacteria, and microscopic and cultural studies confirmed this supposition. Soon the characteristic microorganisms in these tubercles were obtained in artificial culture media and their causal relation to the tubercles was proved by direct inoculation experiments. Moreover peas were planted in sterilized soils and watered with these cultures. When this was done it was found that tubercles formed abundantly on the roots of the plants, which, on account of their ability to fix nitrogen, grew vigorously and produced abundant crops. Additional studies have shown that these bacteria, which are quite widely distributed in the soil, pass into the roots, forming the swelling or tubercle at the place of entrance, penetrate the woody tissue in the

form of delicate f laments, and produce a mucilaginous substance which permeates the tissues of the plant. There has been some discussion as to whether it is the bacteria or the plant which fixes the nitrogen, but the only conclusion which can be justified by the experiments that have already been made is that both of these organisms are essential, both the germ and the leguminous plant are necessary, and they must act together in order to take free nitrogen from the air and combine it into the tissues of the plant. I should state that some experiments indicate that there is a certain amount of nitrogen fixation in the green parts of many plants, but this is so very small compared with the large quantities fixed by the combined action of leguminous plants and the bacteria that it cannot be considered to be of any special importance. In this way it will be seen that there is an association between the plant and the microorganism which is mutually beneficial to the two, and which enables the two working together to take free nitrogen from the atmosphere and build it up into tissue which can be subsequently utilized for feeding other plants and even nourishing animals as well. Home experiments indicate that there are different species of the tubercle organism, and that it is necessary in order to get the best results to bring together the special legume and the special tubercle bacillus which best work together.

It will be seen from this that bacteriology hag been a benefit to the world not only by decreasing sickness and lessening the death rate, but also by pointing out to the farmer a way by which he can utilize the inexhaustible stores of free nitrogen in the atmosphere as a fertilizer for his soil. Moreover it has placed within the hands of man the means by which under intelligent direction the abundance and vigor of life in this world can be increased. It shows us how it may be possible for the arid sandy plain to be converted into a rich field, and how waste places may be fertilized and made to yield abundant food for plant and animal. Just one hundred years ago Sir Humphrey Davy in a popular lecture before the Royal Institution used the following words: "The progression of physical science is much more connected with your prosperity than is usually imagined. You owe to experimental philosophy some of the most important and peculiar of your advantages. It is not by foreign conquests chiefly that you are to become great but by a conquest of nature in your own country. It is not so much by colonization that you have attained your prominence or wealth, but by the cultivation of the riches of your own soil. Why at this moment are you able to simply the world with a thousand articles of iron and steel necessary for the purposes of life? It is by arts derived from chemistry and mechanics and founded purely upon experiments. Why is the steam engine now carrying on operations which formerly employed in painful and humiliating labor thousands of our robust peasantry, who are now more nobly or more usefully serving their country either with the sword or with the plow? It was in consequence of experiments upon the nature of heat, and pure physical investigation. In every part of the world manufactures made from the mere clay and pebbles of your soil, may be found, and to what is this owing? To chemical arts and experiments. You have excelled all other people in the products of industry, but why? Because you have assisted industry by science. Do not regard as indifferent what is your true and greatest glory. Except in these respects and in the light of a pure system of faith, in what are you superior to Athens or to Rome? Do you carry away from them the palm in literature and the fine arts? Do you not rather glory, and justly too, in being in these respects their imitators? Is it not demonstrated by the nature of your system of public education and by your popular amusements? In what then are you their superiors? In everything connected with physical science, with the experimental arts. These are your characteristics. Do not neglect them. You have a Newton who is the glory not only of your own country, but of the human race. You have a Bacon whose precepts may still be attended to with advantage. Shall Englishmen slumber in that path which these great men have opened, and be overtaken by their neighbors? Say rather that all assistance shall be given to their efforts; that they shall be attended to, encouraged and supported." These words spoken by one of the greatest philosophers of England might with scarcely a change in a sentence be addressed to the American people today. If this nation has become a world power it owes its position to the fact that by scientific means it has developed its internal resources, and if the time ever comes when it shall discourage science it will lose the proud position which it now occupies.

I must be permitted to take the time to bring before you one or two additional examples of the great benefit that the world has derived from scientific discoveries which at the time they were made were made were regarded as being possessed of but little importance. The question, What is the use of scientific work? Is an old one. Benjamin Franklin answered this question in his characteristic way by asking what is the use of a baby. What can it do? Let it grow into something and then see. It has been frequently said that the life of Michael Farady was that of a pure scientist. He loved science for its own sake, and he seemed to care but little about any practical uses that might be made of his discoveries, yet as Tyndall, Gladstone and others have shown, a great many of Faraday's discoveries have been applied to practical uses with great benefit to mankind. He discovered benzene, which later, as we all know, became the kernel of organic chemistry. This was converted, as Gladstone has pointed out, into nitrobenzol, a gift to the confectioner and the perfumer. Through the labors of Hofmann all of the aniline dyes with their brilliant colors on fibres of all kinds have resulted from Farady's discovery of benzene. Sir William Thompson utilized the new property of matter discovered by Farady, and designated by him as "specific inductive capacity," in determining the dimensions of submarine cables, and it is said that when Cyrus Field was projecting the Atlantic cable he went to

Farady, talked the matter over with him, secured the interest of the philosopher, asked him some questions, and Farady requested that some time be given him in order that he might correctly answer them. When Field returned Farady said to him: “It can be done, but you will not get an instantaneous message.” “How long will it take,” asked Mr. Field. “Perhaps a second,” responded Mr. Farady. The magneto electric light, which was one of Farady’s discoveries, has for years been utilized in lighthouses and has been designated as “Sentinels of peaceful progress.”

I have often wondered what must have been Farady's feelings when as a member of the committee appointed by the lighthouse board of England he was called upon to pass judgment upon the utility of his own discovery, which had been adapted to practical ends by Holmes. His report shows that he still carried with him the spirit of scientific caution which characterized all his works. I must be permitted to make the following quotation, which shows his cautious spirit most admirably, he states: "The light is so intense, so abundant, so concentrated and focal, go free from under-shadows (caused in the common lamp by the burner), so free from flickering that one cannot but desire it should succeed; but it would require very careful progressive introduction,—men with peculiar knowledge and skill to attend it, and the means of instantaneously substituting one lamp for another in case of accident. The common lamp is so simple both in principle and practice that its liability to failure is very small. There is no doubt that the magneto electric lamp involves a great number of circumstances tending to make its application more refined and delicate; but I would feign hope that none of these would prove a barrier to its introduction. Nevertheless it must pass into practice only through the ordeal of a full searching and prolonged trial."

We are all aware of the great benefit which the discovery of vaccination for smallpox by Edward Jenner has been to the world, but possibly few of us know that nearly twenty-five years of most patient and careful investigation preceded this discovery. The researches of Count Rumford which led to the subsequent discovery of the mechanical equivalent of heat by Joule is another illustration of the great benefit that pure science has been to the world. Dalton's law of definite and multiple proportions, and Avogadro’s statement that under the same conditions of heat and pressure equal volumes of all substances both simple and combined in the gaseous state contain the same number of molecules, have made of modern chemistry a science no less exact than that of mathematics; or, in other words, they have resulted in the application of mathematical exactness to the study of chemistry. I would not have you understand from the statements that I have made that I would restrict scientific investigation to the physical, chemical, and biological studies. As I have already stated, scientific research may concern itself with any department of human knowledge, and certainly some of the discoveries which have been of great force in improving the condition of mankind lie outside of the physical and biological sciences. The comparative study of the Aryan languages, inaugurated by Bott in 1816, has given us greater knowledge of the development of the most important branch of the human family than we could have obtained in any other wav. Likewise the comparative method of investigating social customs and human institutions has shown us how the different groups of mankind in various parts of the world have slowly developed intellectually and morally as well as physically.

As I have already stated, we must not be impatient because scientific discoveries do not always lend themselves to immediate use. It may be said that these discoveries are gems dug from the earth by one generation, cut and polished by the next, and used to adorn the third. During the part hundred years the world has just begun to apply the most brilliant and most important scientific discoveries.

I want to say a few words concerning the conditions which are favorable to the advancement of scientific work, and first I may be permitted to say just a few things concerning the scientific investigator himself. It is sometimes stated that the research man is born, not made. This is of course true, both literally and metaphorically, but by implication it means too much. We know not how many men who might have made great discoveries in science have been born but failed to benefit the world on account of lack of opportunities. The existence of the proper individual is only one of the factors in the production of a scientist. He must have the opportunity, and without it he is practically helpless, or at least the scope of his work is limited, and his strength is fettered. Is it at all likely that the brilliant but somewhat erratic young Welshman who afterwards developed into Sir Humphrey Davy would have made the discoveries that he did had it not been that the Royal Institution offered him the facilities. It is not likely that the unassuming, modest Michael Farady, the son of a blacksmith, and himself an apprentice of a bookbinder, would have made the wonderful discoveries that he did both in physics and in chemistry had it not been that the opportunities for doing so were supplied him by the same institution. Is it not true that the spirit which led to the formation of the Royal Institution in the last year of the eighteenth century was necessary for the development of such men as Davy, Farady, Dalton, Darwin, Tyndall, Huxley, and Spencer. No man can become a skilled workman unless he has the tools to work with. No man, however great his genius, can do scientific work on less he has time and opportunity. A scientific man must have the wherewithal to support life. He must be free from the necessity of looking for the practical ends. On this point please permit me to quote again from Sir Humphrey Davy. He states: "Without facilities for pursuing his object, the greatest genius in experimental research may live on, die useless and unknown. Talents of this kind cannot like talents for literature and the fine arts call forth attention and respect. They can neither give popularity to the names of patrons nor ornament their houses. They are limited

In their effects, which are directed toward the Immutable interests of society. They cannot be made subservient to fashion or caprice; they must forever be attached to truth and belong to nature. If we merely consider instruction in physical science, this even requires an expensive apparatus to be efficient; for without proper ocular demonstrations, all lectures must be unavailing,—things rather than words should be made the objects of study. A certain knowledge of the beings and substances surrounding ns must he felt as a want by every cultivated mind. It is a want which no activity of thought, no books, no course of reading or conversation can supply. * * * To attempt with insufficient means to support philosophy is merely to humiliate her and render her an object of derision. Those who establish foundations for teaching the sciences ought at least to understand their dignity. To connect pecuniary speculation or commercial advantages with schemes for promoting the progress of knowledge is to take crops without employing manure; is to create sterility and destroy improvement. A scientific institution ought no more to be made an object of profit than a hospital or a charitable establishment. Intellectual wants are at least as worthy of support as corporeal wants, and they ought to be provided for with the same feeling of nobleness and liberality. The language expected by the members of a scientific body from the directors ought not to be: 'We have increased your property. We have raised the value of your shares.' It ought rather to be: 'We have endeavored to apply your funds to useful purposes, to promote the diffusion of science, to encourage discovery, and to exalt the scientific glory of your country.'"

As I have already stated, we are fortunate in living in an age which at least partially appreciates and gives some support, although generally inadequate, to scientific research. The Royal Institution of England; founder! by the learned and eccentric American, Benjamin Thompson, or Count Rumford, has for the last hundred years been a great factor in the development of scientific knowledge. It is probably true that there is no other single place in the world where so many great scientific discoveries have had their birth as in the old buildings on Albermarle street. The Pasteur Institute in Paris, now richly endowed and magnificently equipped, furnishes opportunities unsurpassed anywhere for bacteriological research. Already the contributions made through there institutions to the progress of science and the betterment of the human race have more than justified the expenditures that have been made in carrying on the work. Indeed, the researches of Roux and Metschnikoff, to say nothing of those of many of their assistants, have given us information by means of which many lives have been saved and the domain of human knowledge has been greatly extended. We are still accustomed to look upon Russia as a half civilized country, but the appreciation that this great vigorous nation is showing for scientific research is bound to make Slavonic civilization a powerful competitor in the future history of the world with Anglo-Saxon culture. The laboratories of experimental medicine grouped together on one of the islands of the Neva near St. Petersburg furnish probably the most ideal place for scientific research now existing in the world. The government has erected capacious laboratories, has equipped them with the latest and most improved instruments of precision, and has called to these laboratories its most eminent scientific men, and has imposed upon them no other tape than to search for truth in the biological sciences. As we all know, scientific research has been most warmly nurtured for the last fifty years in Germany, and this has done more for the solidification and permanence of the German Empire than has been accomplished by political means. Her numerous universities are liberally supported by the state, abundantly supplied with facilities and her best men are called to occupy her professorial positions. Not only has this been done, but the Kingdom of Prussia alone has built at Charlottenberg at a cost of twenty-one millions of marks a great polytechnicum in which eminent physicists and chemists devote their lives to the pursuit of knowledge. In emulation of Paris, Berlin has the new Institute, turned over to Koch for his researches along medical lines, and the Imperial Government has established at Frankfort a laboratory of research which is under the direction of Ehrlich, who is probably the most gifted man in physiological work now living. There are indications that some of the wealthy men in our own country are beginning to appreciate the great value of scientific research. The recent establishment of the Rockefeller Institute, and the still more recent gift of Mr. Carnegie for research work, are illustrations along this line. The United States government has sustained certain lines of research which have been very creditable but it must be admitted that political influences have had more to do with the establishment of the scientific bureaus at Washington than love of science itself. While a great deal of valuable work has been done in the bureau of animal industry, and in other departments, notably at the Smithsonian, the object had in view in establishing and maintaining these laboratories has been more directly for the purpose of securing votes than it has with any full appreciation of the value of scientific discovery. However, I do not desire to pose as a critic of my own country or as one who always sees things to admire abroad and things to condemn at home, and I believe that the future for scientific research in this country is as bright as that in any other part of the world. If we are to continue to move ahead, this must be true. Even if we have no higher aim than that of commercial supremacy, which this nation seems to be fast acquiring, we must encourage scientific research. There are many problems in applied science, the solution of which must be demanded very soon. Some of these may be briefly mentioned. Our dairy products are known to be inferior to those of certain other countries,—notably Denmark. This is largely, if not altogether due to the fact that in Denmark cream is always pasteurized and is then inoculated with a culture of germs which have been found to give the best flavor. This of course tells largely in butter making. The ripening of cream is due to the growth of germs and every cubic centimeter of ripened

cream contains an average of about four hundred millions of bacteria. At present in. this country the kind of germs present depends upon the accidental contaminations of the various barnyards in which the milk is gathered, and of course no uniform result is obtained. In Denmark the law makes it obligatory upon every maker of butter to pasteurize the cream by heating it to a temperature of 70°-72° and then allowing to cool. This destroys all the germs present, and then the cream is inoculated with cultures of those germs which have been found by experience to be beneficial. The pasteurization of all milk which goes to a creamery in Denmark has the advantage not only of securing for Danish butter several cents a pound more in the English markets, but also of destroying the tubercle bacillus, which may be present. Sterilization and subsequent inoculation with pure cultures gives a butter which is uniformly good. It is true that in this country pure cultures, known as starters, have been employed to some extent, but as a rule these cultures are added to unsterilized cream. In other words, they are mixed in with the germs that are already growing in the cream. After this, it depends upon accident which will crowd the other out of existence. We need a more thorough study of the bacteriology of cheese, because the flavor of this very valuable article of diet is largely dependent upon the bacteria and molds present. There is also room for improvement in many other food articles which we export. There is opportunity for most excellent work to be done upon the blending of wheats in order to secure a flour that will make the best bread. We have vast areas of practically sterile lands which under the influence of scientific agriculture might be made to support a large population. The question of the disposal of sewage is an important one. Ordinarily it is thrown into rivers or other watercourses, and pollutes our streams, serves as a means of spreading disease, and robs our soil of its most valuable constituents. Some experiments have been made already upon a small scale and seem to indicate that certain bacteria may be used for the purpose of converting the organic matter in sewage and garbage into nitrates and nitrites which might be again used in fertilizing the soil. A proper solution of this question will lead not only to the prevention of such water borne diseases as typhoid fever, but must add greatly to the productiveness of our soil. We need improved methods of making artificial stone and similar building material. We have great beds of marl, but at present the demand for this material is somewhat limited, and I have no doubt that the time will come when this substance will be put to uses much more important than any in the past. There are many other problems awaiting solution but time will not permit me to discuss them.

DOUGLASS HOUGHTON.

"He loved the study of the operations of nature in the midst of her wildest scenes."—*Bela Hubbard*.

As a man. Dr. Houghton is described by his friend and biographer, Alvah Bradish, as slightly below the medium height, his head was large and well developed, his hands and feet small and delicately formed, his nose prominent, his eyes blue tending toward hazel, and bright and merry and expressed his feelings without disguise. His temperament was warm and nervous, his movements quick and earnest. His voice rang with the melody of unaffected enjoyment, or the gayety of social and confiding intimacy. His sensibilities were feminine in delicacy. He saw the importance of making friends of political leaders, and had a faculty of inspiring others with his enthusiasm, and of awakening a profound interest in his pursuits. He was young, ardent and generous to a fault. He did not confine himself exclusively to the study of science, but engaged in business enterprises, and as is shown by his being mayor of Detroit, took a deep interest and exerted a directing influence in affairs of state, being at the same time quite above and outside of political parties. These many more broad, generous, and noble qualities may be found recorded in the biographies of the subject of this sketch, the most eminent of the pioneers of science in Michigan.

DR. DOUGLASS HOUGHTON.

The leading events in. the short but useful life of Dr. Houghton may be briefly summarized in a few paragraphs. He was born at Troy, New York, on September 21, 1809; passed the greater part of his boyhood at Fredonia in the same state; studied at the Rensselaer high school under Amos Eaton, and was graduated from that institution in October, 1829, but remained there as an assistant instructor and assistant professor for about one year. He delivered a course of public lectures on geology and kindred sciences in Detroit during the winter of 1830-31. Having studied medicine, he was admitted to practice by the Medical Society of Chautauqua county, New York, in the spring of 1831. At this period he was appointed physician and botanist on an expedition to the sources of the Mississippi under the leadership of the distinguished explorer Henry R. Schoolcraft. His experiences on this expedition beyond the frontier as then known, seems to have intensified an inherent love for the charms pf nature and led him later to assume leadership in still more extended explorations and discoveries. His report on the botany of the region-visited with Schoolcraft, as is stated by Bela Hubbard, shows not only an exhaustive acquaintance with, the branch of science with which if deals, but did much to extend the world's knowledge of the flora of the Northwest, and to establish his own. reputation as a scientific observer. From 1832 to 1837, he practiced as a physician and. surgeon in Detroit, and during that period rendered highly important service at a time when the city was stricken with cholera. In February 1837, he was appointed State Geologist of Michigan, and thence forward to the day of his death, devoted the greater part of his time and almost his entire energy to the study of the geology of his adopted State. In 1838 he was appointed professor of geology, mineralogy and chemistry in the University of Michigan, a position which he retained until the close of his busy career. In 1833, he was married to Miss Stevens of Fredonia, New York, who, together with two children survived to mourn his death, which occurred on the night of October 13, 1845. His death was tragic; while prosecuting his arduous and frequently hazardous explorations on Lake Superior, in an open boat, he was overtaken by a severe snow storm, his boat was capsized near the mouth of Eagle river, and he, with one companion, was drowned. His body was recovered the following spring and buried in Detroit.

"Thus, at the early age of thirty-six years, was lost to his state and science one who, without eulogy, may be ranked among the most extraordinary men of our country; whether we view him as the humble student of nature, attracting all hearts to science; the friendly and skillful physician, periling his life to save that of others; the energetic and independent public man, untiring in his energy and sacrificing his private means in the public cause; or the university instructor of youth and age, the source of as frequent and general reference as the pages of a cyclopedia."—*Bela Hubbard*.

The esteem with which Dr. Houghton was held by those who had the privilege of knowing him personally, both on account of his many attractions as a man and his wide scientific attainments, is suggested by the following from the many similar quotations that might be made.

"Simple as a child, and unassuming as he was scholarly, he wrote his name on the history of his state, there to remain forever."—*Lyman D. Norris*.

"I believe we never had a citizen who did more for the future of the state than Dr. Douglass Houghton."—*James V. Campbell*.

"The honesty, skill and enthusiasm with which this field of work [the exploration of Michigan] was executed, resulted in the collection of a large amount of geological data, which on the completion of the survey would have left little to be done save the final report with which the master mind should classify, group and harmonize these facts and thereby develop nature's laws from the mass of material collected."—*T. B. Brooks*.

"Dr. Houghton's report, published in 1841, furnished the world with the first definite information relating to the occurrence of native copper in place on Lake Superior, and the mining interests now rapidly growing up in that region have been to a great extent created by the attention he directed to it."—*Alexander Winchell*.

The memory of Douglass Houghton has its most noble monument in his own publications, although these, on account of his death before his field notes could be systematically studied, are few in number; but in addition, his countrymen have acknowledged his services on the map of Michigan by a county, a lake and a city named in his honor. A memorial window dedicated to him, was placed in St. Paul's church, Marquette, in 1887, as a tribute to his memory from one who valued his work tout did not know the man. The Douglass school in Detroit is named for him. A granite shaft erected by his wife, marks his last resting place in Elmwood cemetery; and his name with an appropriate epitaph, is enscribed on a marble column in the campus of the University of Michigan. A portrait, painted by Alvah Bradish, has been placed in the capitol at Lansing.

Douglass Houghton's principal publications relate to his work as State Geologist of Michigan, and are comprised mainly in seven annual reports. A final report I believe was never begun. Some of his explorations and surveys in Michigan were conducted under the auspices of the U. S. Land Office, and the results appeared in part in certain maps issued by that office, and in other ways. A list of his writings, published both by the State of Michigan and by the federal government, is contained in Vol. VII of the reports of the Geological Survey of Michigan.

The principal memoirs of Dr. Houghton, and the ones from which this imperfect sketch has been prepared are as follows:

“Memoirs of Douglass Houghton, first State Geologist of Michigan, by Alvah Bradish, page i-xii, 1-302. Detroit, 1889. The frontispiece of this volume is a reproduction of its author's portrait of the subject of the memoir. In the appendix of the Volume selections from the letters of Dr. Houghton are presented, and also a very full account of his published reports on the geology of Michigan.

“A Memoir of Dr. Douglass Houghton, late State Geologist, and Professor-of Geology and Chemistry in the University of

Michigan [by Bela Hubbard], in The American Journal of Science and Arts, Vol. V, 2nd series, 1848, pp. 217-227.

"Douglass Houghton" by Alexander Winchell, in The American Geologist, Vol. IV, 1889, pp. 129-139, with portrait.

"The soldier dies honored who falls in battle. He too perished on the field of his fame—a field whose victories are bloodless, and in whose fruits untainted by misery and crime, the whole human family may rejoice."—*Bela Hubbard.*

BELA HUBBARD.

The subject of this sketch enrolled his name among Michigan's votaries of science, by his work as assistant geologist on the Geological Survey of his adopted State, and by writing a thoroughly reliable and most attractive book, entitled "Memorials of Half a Century."

The history of the life of Bela Hubbard, when fully and sympathetically written, will contain at least five important chapters, which may appropriately bear the captions: The man, his private life, affections and friendships; the student of nature, his explorations and observations; the man of business, his defeats and successes; the student of history, his researches and aid to fellow students; the citizen, his influence on the State's aid to science. Only the barest outline, however, of the several ways in which his long and useful life should be described and commemorated, can be presented at this time.

Bela Hubbard was born at Hamilton, New York, April 23, 1814, and died in Detroit, Michigan, June 13, 1896. He was the son of Thomas H. and Phebe Hubbard, and passed his boyhood days at their home in Hamilton. He was graduated from Hamilton college in 1834, removed to Detroit the following year, and soon after became connected with the Geological Survey of Michigan. Later he entered his brother Henry's law office and was admitted to the bar in 1842. The greater part of his life was passed in Detroit, and he became thoroughly identified with the life and development of that city.

As the writer of this sketch has been informed by Mr. C. M. Burton, who was a friend and companion of Bela Hubbard during his mature years, and to whom the reader is indebted for nearly all the facts here presented, he was below the medium height, slightly built, not very robust, light complexioned, with blue-grey eyes and brown hair; and possessed a quiet temperament and was not easily excited. As a friend, companion, and fellow student in historical and other researches, he was a kindly and lovable man. He was married in 1846, to Sarah E., daughter of Rev. John A. and Sarah (Harvey) Baughman, in 1848. The literary tastes and attainments of his wife, are indicated by a book from her pen, entitled. "The hidden sin," published in London, and republished by Harper Brothers, in 1866. Several children were born to Mr. and Mrs. Hubbard, of whom two daughters and one son still live.

Soon after removing to Detroit, Bela Hubbard became acquainted with Douglas Houghton, then State Geologist of Michigan, and in 1837, was appointed Assistant Geologist on the State Geological Survey, a position which he held until 1841. He accompanied Douglass Houghton on an important expedition to the southern shore of Lake Superior, in 1840, an account of which is given in his "Memorials of half a century." It is this book more than anything else that will preserve the memory of its author. It is his most fitting and most enduring monument and entitles the name of Bela Hubbard to a place on the short list of American authors who may be justly termed "nature writers."

The book just referred to covers a wide field, as for example, the scenery of the Great Lakes, experiences of explorers, historical and antiquarian sketches, studies of plants and animals, critical discussions of climatology, essays on the seasons, etc. Throughout all of its many chapters is seen the ability of its writer to observe critically, generalize judiciously and record truthfully and graphically. In its pages, more faithfully perhaps than a stranger would infer from its title, are the painstaking studies of half a century epitomized.

One of the most charming features of Bela Hubbard's writings is the reflection from them of his strong love of nature. To justify this claim permit me to transcribe three independent passages from his "Memorials," descriptive of our northland in spring, in summer, and in autumn:

"And now, while the mists are yet in the valley and on the river, awakes the nuptial chorus of the birds. And what a concert it is! As if each little musician had aroused to a fresh sense of his happiness, and was striving to outdo all others in the expression of it. The whole air is vocal. The strains mingle in a confused medley, yet in perfect concord. Not one throat that ever poured a note is silent now. One after another takes up the strain, ever higher and higher, nearer and nearer, until the very heaven resounds, and 'Earth rolls the raptuous hosanna round.' If you would hear this sweet concert delay not until the sun is up, and not until the summer. It is the birds' epithalamium. Its set time is the dawn in spring."

"What a month of months is our Northern June! The trees lately so bare, or showing only the delicate tints of spring, have now perfected their foliage, and are fresh and lustrous as young brides adorned for their husbands. The evergreens are illuminating their sombre mourning suits with an embroidery of a new and lighter growth, that, like half-tints in a widows weeds, betoken relief from the thraldom of sorrow, while they add enhanced beauty. How richly green the soft carpet that covers the ground! What land can compare with ours, at this season, for diversity of leaf and tint, and depth of color? Where is the tropical landscape that, with all its luxuriance, can compete with it, or that can compensate by its tangle and variety for the absence of turf? Trees and grass make a paradise of any Northern home, nor need we envy those sun-burned lands where that chief element of beauty—the greensward—is wanting."

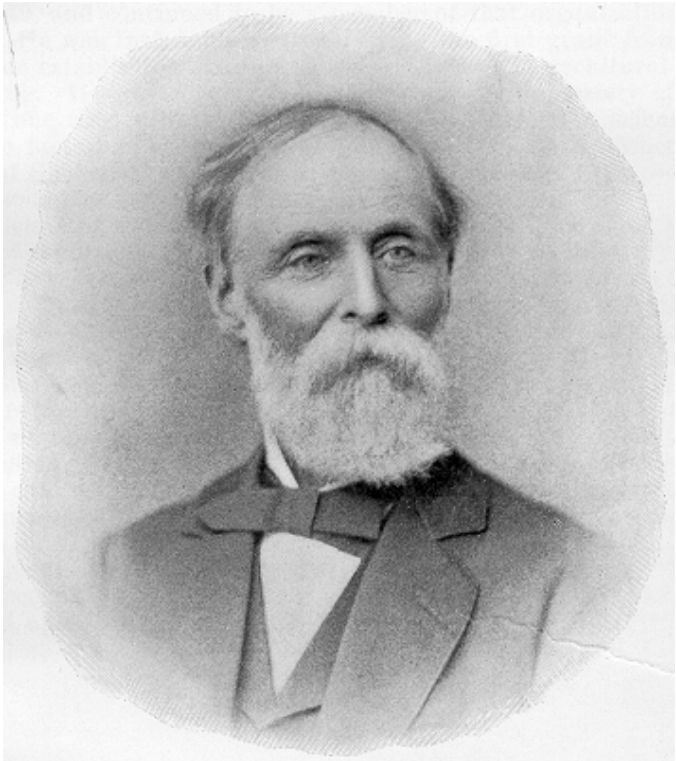
"Yet the Indian summer is no myth. It often breaks upon us from the very midst of storm, frost and snow, true to the tradition, that there must first be a 'squaw winter' before we can have an 'Indian summer.' At once the icy blasts are locked securely in their northern caves, the snow melts and the earth dries under a genial sunshine. The calm, still atmosphere is filled with a smoky haze, which hangs like a veil over the landscape. Day after day succeeds of most delicious, dreamy

softness; not enervating like the heats of summer, but exhilarating to soul and body. For the rains and the frost have purified the atmosphere, renderng it elastic and bracing. The sun's rays have lost their power to oppress, and bring only enjoyment. How softly his beams fall on all surrounding objects—the gold without the glitter. What a delicious atmosphere; we can almost fly in it!

'—— how soft the blue,
That throws its mantle o'er the lengthening scene.'

'Neither Eastern climes nor rural England can produce anything to compare with this balmy sunshine and this glorified landscape, shrouded in the hazy canopy of Indian summer!"

In addition to the popular book from which the above quotations have been taken, Bela Hubbard, jointly with W. A. Burt, wrote a small book on the geography, topography and geology of the south shore of Lake Superior, published in 1846. Among his minor writings are included an essay on the "Early colonization of Detroit," published by the State Pioneer Society; and a discussion of the "Climate of Detroit," printed in the American Medical Observer.



BELA HUBBARD, LL D.

Soon after Bela Hubbard removed to Detroit, his father presented him with a farm, situated about two miles from the west limit of the city. In later years owing to the growth of Detroit, this farm became included within her boundary, and greatly increased in value. A handsome boulevard which now passes through this tract bears its former owner's name. The demands of his property interests led Bela Hubbard to open a real estate office and deal in landed property. His business enterprises, although attended by certain embarrassments, were on the whole highly successful and he became a man of means as well as of municipal and social influence. His deep interest in the welfare of Michigan is shown by the fact that he was one of the organizers of the State Agricultural Society in 1849, and continued to be a member of that organization for many years. He was instrumental in obtaining the first grant from the Legislature for establishing the now flourishing State Agricultural College at Lansing. He was a member of the Young Men's Society of Detroit, and at one time (1845) its president. His interest in science is shown by the fact that he was one of the organizers of the American Association of Geologists and Naturalists, the fore-runner of the present American Association for the Advancement of Science.

Although Bela Hubbard is justly claimed by the scientific men of Michigan, as one of their number, his talent is recognized by our literary and historical brethren, as well. He was an enthusiastic student of the early history of Michigan, and an admirer of Pere Marquette, whose trails he crossed during his expeditions to Lake Superior, and from whose example he seemingly acquired a longing for the free, adventurous life of the explorer. His interest in the history of the French occupation of the Great Lakes region led him to search in person as-well as assist others engaged in a similar task, among the archives of Paris, for original data in that connection. As a monument to his tastes for history, although no such thought can be ascribed to him, as well as to the pioneers who unfolded the wonders of the New World, he had executed and presented to the citizens of Detroit, the statues of Cadillac, La Salle, Marquette and Richard, which decorate the four corners of their City Hall. In heartfelt recognition of his scholarly attainments, the degree of LL. D., was conferred upon him by his *Alma Mater*, in 1893.

I. C. R.

MAGNETIC PHENOMENA AROUND DEEP BORINGS.

BY A. C. LANE, STATE GEOLOGIST.

In an early paper by Prof. Alexander Winchell he calls attention to magnetic phenomena around certain springs in the State, but without specifying precisely what these phenomena were. It is also noteworthy that a large number of the springs or rather artesian wells, that have been exploited as mineral waters, have "magnetic" in their name* or like the St. Louis spring make reference in their circulars to their magnetic powers as of great value. In the course of my studies on the water supply of Michigan, and in the examination of other borings of various kinds, which is part of my regular business, it became a matter of some interest to know just what these magnetic phenomena were. So far as I could find out they were of two kinds. All the wells in question are drilled wells in iron casing, and even when this casing was said to be wrought or soft iron it had a considerable attraction. It would for instance hold out nails, and the pull upon a wrench could very readily be felt. Sometimes too, it was noticed that the blade of a knife immersed in the water also became magnetic. Of this last statement I may remark that while it is very easy for knife blades to have become magnetic without the owner's knowledge yet there is no reason to doubt that in some cases knife blades did really become magnetic. However, I do not know of any case where the knife blade became magnetic except as it was held in the water as it flowed from the casing, and hence close to the latter. Now any knife blade being steel if it is held close to a magnet will soon become permanently magnetized itself, so that the two phenomena reduce themselves to one, mainly the magnetism of the casing. As to any well defined magnetic effects of the waters of a medical nature I am not qualified to judge, not being a physician, nor have I had them stated to me in any tangible state. Now in regard to the casing, we must remember that the earth as a whole is a magnet and electro-magnetic currents are continually flowing in it, and that any iron rod or tube lying in a magnetic field and cutting the lines of force will itself be magnetized, just as a soft iron nail touching or close to a magnet will itself become attractive and be able to draw a smaller nail. Applying this to the case of these deep wells we have continuous lines of iron pipes, of wrought iron or steel (and sometimes pipe that is sold for wrought iron is really steel), which may vary in length from a hundred feet to two or three thousand or more and it is not surprising that they should be magnetic as they cut a good many lines of force of the great earth magnet. These lines are represented in a horizontal direction by the compass and in a vertical plane by the dip needle. If this explanation of the magnetism is correct, then all strings of casing should prove to be more or less magnetic. Such indeed I have found to be the case very often to the considerable surprise of the owners thereof, though well drillers tell me that they know this to be the rule. This magnetic force is sometimes very considerable. It will often hold out the largest size of spike, and I believe in the case of the well over five thousand feet deep, tested by Prof. William Hallock of Columbia Univrsity, it could hold a wrench. I have found that in lowering a thermometer down these wells the steel tape clung to the sides so that it made a material difference in the energy required to handle it. It was just about as much as a man could do to start 2,600 feet of steel tape from the Grayling well, although the weight of the tape itself would not be over 25 pounds. Again in measuring the depth of a well recently sunk at Cheboygan, 2,700 feet deep or more, Mr. Rust the driller, informed me that the magnetic drag on the tape was such that it was also impossible to tell when the 20 pound weight was at the bottom. At the same time it seems to me that the magnetism is not directly proportional to the depth of the hole alone, although the larger and deeper holes are of course in a general way more magnetic, and I should think there might be interesting opportunity for some student of geophysics to make some magnetic observations of considerable interest. The university of Michigan has for instance put down recently a well dome 1,300 feet deep, which at one time, if not at present, was cased over a thousand feet. It would seem that here might be a good chance for careful experiment. I should be very glad to have any suggestions from students of physics as to how observations upon these phenomena could be made more definite and instructive. Before closing I would like to mention another phenomenon though it does not occur in a deep boring but in a deep shaft. The Tamarack mine has recently sunk a shaft (No. 5), which goes vertically downward some 4,666 feet before it encounters the lode which the mine is working. In preparing to connect this with the old workings of the mine two plumb bobs or pendulums were let down the shaft 4,250 feet, and whereas they were 17.58, or at another time 16.33r feet apart at the top, they were found to be 17.65 respectively 16.42 feet apart at the bottom. In No. 2 shaft the divergence was from 12.6 feet at the top to 12.7 feet at the bottom. This divergence was unexpected, but Prof. W. Hallock of Columbia who has investigated the matter, concludes that it is a phenomenon of a character similar to those we have described that the long wires in the magnetic field of the earth were magnetized, so that the similar poles repelled each other as they always do. He adds, "I may say that, as far as the magnetizing influence of the earth upon the casings is concerned, it would matter but little whether the pipes were really wrought iron or steel, because, inasmuch as they remain in the magnetic field, they would of course remain magnetized, even if they were soft wrought iron.

"A factor which probably influences the strength of the magnetism of these casings is the number of strings that may be put into any particular well. In the well at Wheeling there were, I believe four strings, the longest one being something over 1,500 feet. In that well it proved impossible to sink a steel tape through the casing, even with a 50 pound weight attached to the

lower end of it. In my temperature observations a steel wire was used which of course adhered to the walls of the well but little."

Farther investigation at the Tamarack Mine by President McNair showed that the phenomenon there was mainly due to the draft of air.

*Such as Midland Magnetic, Grand Rapids Magnetic, Riverside Magnetic at Detroit, and Magnetic Springs at Leslie, Lansing, Fruitport and Hubbardston, the analyses of which are given in Water Supply Paper No. 31 of the U. S Geological Survey.

A REMARKABLE DUST SHOWER.

BY C. D. MCLOUTH.

On January 27 of the present year (1902) a shower of dust fell over a wide area in Western Michigan. The dust was mingled with snow and the mixture was commonly mentioned as yellow snow. The fall of the dust continued during a considerable part of the afternoon,—three to seven hours according to observers at different stations.

The fall occurred during the subsidence of the anticyclone following a storm of great energy that crossed the continent during several days preceding. The storm moved from northern California southeastward to Kansas, thence curving northeastward to Lake Superior. During and following this storm strong winds were prevalent over a wide region that came under its influence, although the winds were not exceptionally high. On the date of the dust fall and the preceding day the winds over the lakes and Mississippi valley were westerly.

Along the coast the dust is known to have fallen as far south as Holland and at Hart northward, indicating an extreme width of at least sixty miles. It is known to have extended inland to Sparta, about thirty miles from the lake shore. The territory bounded by a line slightly outlying: these points is not less than 1,600 square miles in area. It appears that the precipitation was somewhat variable in quantity at different places and there are some indications that the amount was greater twenty to thirty miles inland than at Muskegon.

Naturally there were many speculations as to the real nature of the phenomenon. The dust was variously mentioned in public print as (1) local surface material, especially from the dunes along Lake Michigan; (2) Volcanic dust; (3) Meteoric matter; (4) Earthy material raised from the surface beyond the lake. The first supposition was easily disproved by microscopical measurements of the grains, which showed its extreme fineness as compared with local soil particles. Moreover, the fall was observed on Lake Michigan windward from the land. The presence of considerable organic matter showed that it could not have come from a volcano or from outer space. Dr. A. C. Lane, State Geologist, pronounced the dust identical with the loess soil of the Mississippi and Missouri river valleys. Mr. W. A. Orton of the National Bureau of Plant Industry called it fine silt. Thus the problem was narrowed down to finding the exact source of the material and how it could have been raised and transported so great a distance under conditions that did not seem exceptional.

Some attempts were made at collecting data from which an approximate estimate of the total deposit could be formed. Snow containing the dust was taken from measured spaces and the dry residue weighed with results as follows:

Number.	Place of collection.	Collector.	Area in square feet.	Dry weight in grams.	Weight per square foot.
1	Muskegon	C. D. McLouth	1	1.855	1.855g
2	Ravenna	C. E. Alberts	1	3.464	3.464g
3	Muskegon	C. D. McLouth	4	3.417	.854g
Average per square foot					2.058g

On the basis of the average found the precipitation on a square mile would be about six and one-third tons; on the total area as indicated above the amount would be about ten thousand tons.

I also weighed two residues which, though not affording accurate data, are significant.

Mr. G. A. Rumsey, of Slocum, about twenty miles due east from Muskegon, filled a common drinking glass with the snow and obtained therefrom a dry residue that weighed 0.29 grams.

Ray Dawes, a pupil in Muskegon high school, collected a large panful of the snow found clinging to trunks of standing trees on the windward side. This melted to three quarts of water and yielded sixty-five grams, approximate weight.

The following notes are quoted from some of the correspondents to whom samples and inquiries were sent.

C. E. Alberts, Ravenna.—"The dust almost spoiled the sleighing."

L. L. Coates, Sparta.—"There are several pounds of it (the dust) in my cistern."

C. E. Ruthruff, Montague.—"That deposited here was coarser than the sample you sent, and had a decidedly red color." (Statement not verified by a specimen).

Vernon G. Mayo, Newaygo.—"On an inclined walk usually ashed to prevent slipping, it was abundantly deposited, so no ashes were needed."

D. E. Austin, Blue Lake Township, near Whitehall—"The sand or dust storm was of seven or eight hours duration. * * * The dust coming in swirls was deposited at right angles to the course of the storm, in some places scarcely a trace, then again sufficient to check the motion of a sleigh. * * * In breaks of the snow storm the dust would appear like great yellow smoke columns above the level of the main storm clouds."

In physical form the dried material resembles flour. The particles, which are generally angular and irregular, range in diameter from .005 to .00005 of an inch, few

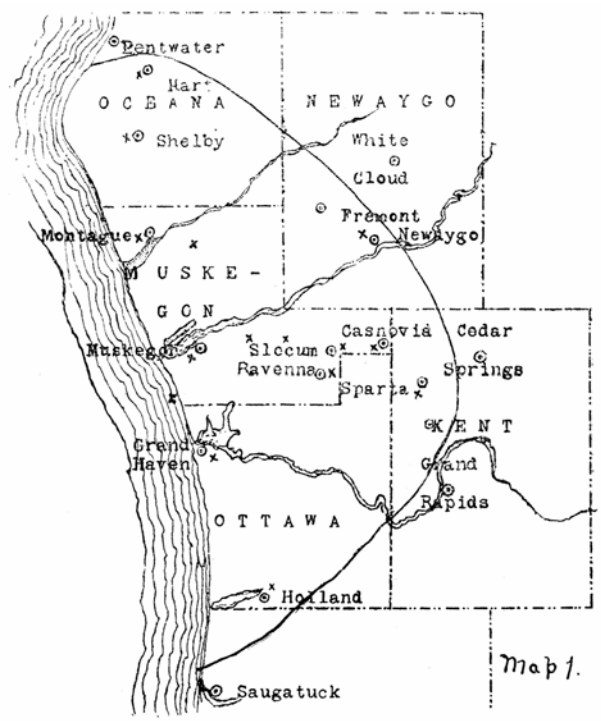
grains reaching the larger dimension. Its color is a deep shade of yellow-orange. It sinks readily in water and m semi-pasty when wet.

In composition the material is chiefly silica. About five per cent, according to Mr. Orton, is organic matter, such as plant hairs, pieces of wood fiber, desmids, etc.

As is well known, dust storms are common in many parts of the world. In Michigan they seem to be rare but are not unknown. Mr. L. L. Coates informs me, on authority of Mr. George H. Porter, of Sparta, that a similar storm occurred at that place in 1873. On February 18, 1896, Mr. Herman P. Thomas of Cassopolis witnessed a dustfall there. He weighed a collection from a measured space from which he computed 245 pounds per acre, a quantity greatly exceeding that indicated by measurements in the recent instance.

The Monthly Weather Review of January, 1895, contains a detailed account of a dust storm in parts of Indiana and Kentucky with results of careful analyses of numerous samples of the material.

In all these instances the material seems to have been nearly or quite identical with that of the recent storm.



1. A map showing approximately the extent of the dust shower in western Michigan, January 27, 1902.

Places at which the dust is known to have fallen are marked with *x*.

Extent from north to south along the lake shore about 60 miles.

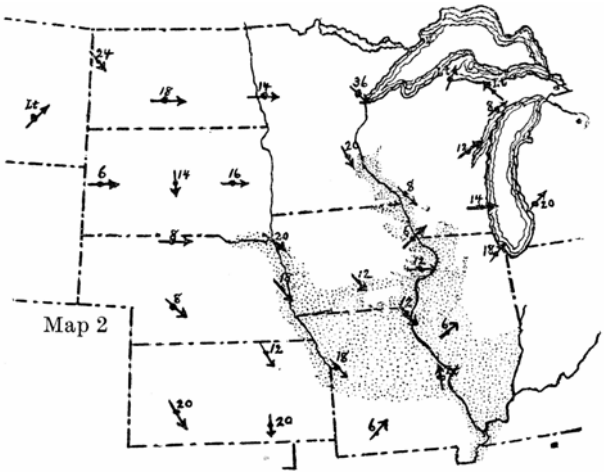
Greatest extent eastward from shore about 30 miles.

Average amount of dustfall per square foot based on three measurements 2.058 grams.

Estimated amount of dust deposited on one square mile, 6.33 tons.

Amount computed for area of 1,600 square miles, about 10,000 tons.

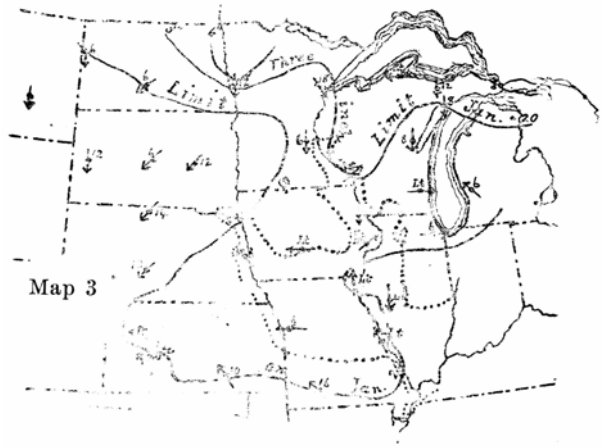
In attempting to explain the raising and transporting for so great a distance of this mass of soil all readily available data were acquired relating to (1) wind directions and velocities, (2) distribution of loess, (3) snow covering in the loess regions. The officials of the U. S. Weather Bureau both at Washington and at the Grand Haven station kindly furnished an abundance of meteorological data by maps and otherwise. These were diligently studied to find indications of a possible bare spot of loess where the prevailing wind could have done the work.



Map showing wind directions and velocities in relation to loess soil regions January 26, 1902. Data taken from reports of U. S. Weather Bureau.

Snow covering was essentially as shown on map of January 27.

The loess is shaded.



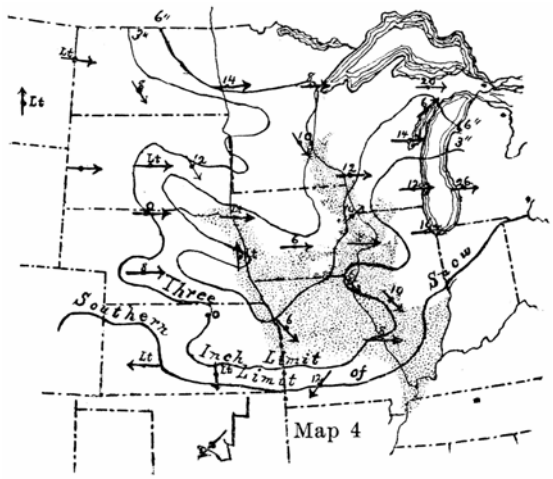
Map showing wind directions and velocities, also approximate extent of snow covering, in relation to loess soil regions, January 25, 1902.

Meteorological data taken from reports of U. S. Weather Bureau.

Approximate boundary of the loess is shown by dotted line.

The known extent of loess in the United States is in comparatively narrow belts along the rivers Mississippi, Missouri and Ohio. Its nearest approach to Grand Haven is in southern Wisconsin, distant 150 miles. It extends westward across Missouri and southern Iowa

beyond Omaha and Sioux City, more than 500 miles from the east shore of Lake Michigan.



4. Map showing wind directions and velocities, also extent of snow covering, in relation to loess soil regions, January 27, 1902.

Meteorological data taken from reports of Weather Bureau. The loess is shaded.

On January 20, just one week before the dustfall, the loess region, except in the Ohio valley was mostly under a thin cover of snow. On the date of the shower the area of snow had been greatly extended, especially westward, and the depth considerably increased. Much of the loess was then under six inches and more of snow, but the tract nearest to us in southern Wisconsin was outside the three inch limit and some of it may have been practically bare. In middle Nebraska, South Dakota and in southern and western Illinois the snow covering was also light and in these regions there may have been some exposed soil. These conditions had remained essentially unchanged during 48 hours or more preceding the dustfall. It remained then to choose whether the dust had probably been raised in remote parts and its long transit made longer in time and space by shifting winds or whether it had been transported from the nearest locality in the course of a few hours.

On January 25, when the storm center was far west, the winds were light and mostly from eastward over the Mississippi and lower Missouri valleys. The snow cover had not been materially increased since the twentieth but there was not sufficient energy in the winds to disturb an exposed surface of the lightest soil. On the following morning, after most of the new snow had fallen, the winds were decidedly stronger and mostly from westward. The highest velocity reported by the Weather Bureau was 36 miles per hour at Duluth. Other significant records were: St. Paul, 20; Milwaukee, 14; Des Moines, 12; Davenport, 12; Sioux City, 20; Omaha, 18; Chicago, 18; Kansas City, 18. These velocities are not high but they indicate a general movement of air currents of considerable force.

On the twenty-seventh the general direction of the winds was from the west but velocities had become much lower west of the Mississippi. In the lake region velocities remained about as on the previous date, as follows: Grand Haven, 26; Milwaukee, 12; Green Bay, 14; Chicago, 16. These it must be understood were not maximum velocities but velocities at moment of taking data for the daily report. At Grand Haven on this, date the maximum 1-minute record was 42 miles per hour at 9:17 a. m. and the maximum 5-minute record was 37 miles per hour at noon. Quite probably there was a similar rise in velocities above the morning records at stations on the west side of Lake Michigan, and these strong winds may have caught up the material in southern Wisconsin during the forenoon and swept it across the lake at 50 miles per hour in the upper cloud regions.

It is plain that the evidence I have been able to accumulate up to time of writing is quite insufficient to make a satisfactory demonstration. At first thought it seemed that only a spiral wind of tornado violence could have lifted such a mass high in air where it could be sustained and carried on air currents that probably did not exceed a velocity of 50 miles an hour, but no disturbance of that nature is indicated in any of the weather reports. The dust was raised and carried by winds that are frequently exceeded in violence and equalled in constancy. It would seem therefore that we should have about twenty dust showers each year rather than one in about twenty years.

Besides persons and institutions named before I am indebted to Mr. Frank Leverett of the U. S. Geological Survey for important information on extent of the loess, also to numerous correspondents through whom I have been able to approximate the limits of the fall.

Muskegon, March 26, 1902.

WIDTH OF MEANDER BELTS.

BY MARK S. W. JEFFERSON, PROFESSOR OF GEOGRAPHY STATE NORMAL COLLEGE, YPSILANTI.

(Full Paper in National Geographic Magazine. Extract of Conclusions Read).

The meandering of rivers is known to vary with their size. Of those streams of gentle gradient which affect a winding course, the larger wander farther from side to side.

An attempt to determine the relation between volume and width of meander belt failed from insufficiency of available data, but suggested that width was far the most important element of volume to affect meandering.

From a study of the best mapped rivers in Europe and this country it appears that the extreme width of country over which the meanders range from side to side before being abandoned by "cut-offs" in the course of the river is about 18 times the width of the stream when bank full. Thus a stream with well marked banks averaging 100 feet apart may meander from side to side over a belt of country 1,800 feet wide. At this width cut-offs are almost certain to occur. They often occur at far less width.

The argument is empirical from tabulated measurements. Theoretical considerations are cited to account for tendencies, i. e., qualitatively, but no reason is found for the ratio 18 to 1.

Exchanges should be sent to Dr. G. P. Burns, Librarian, Ann Arbor, Mich.