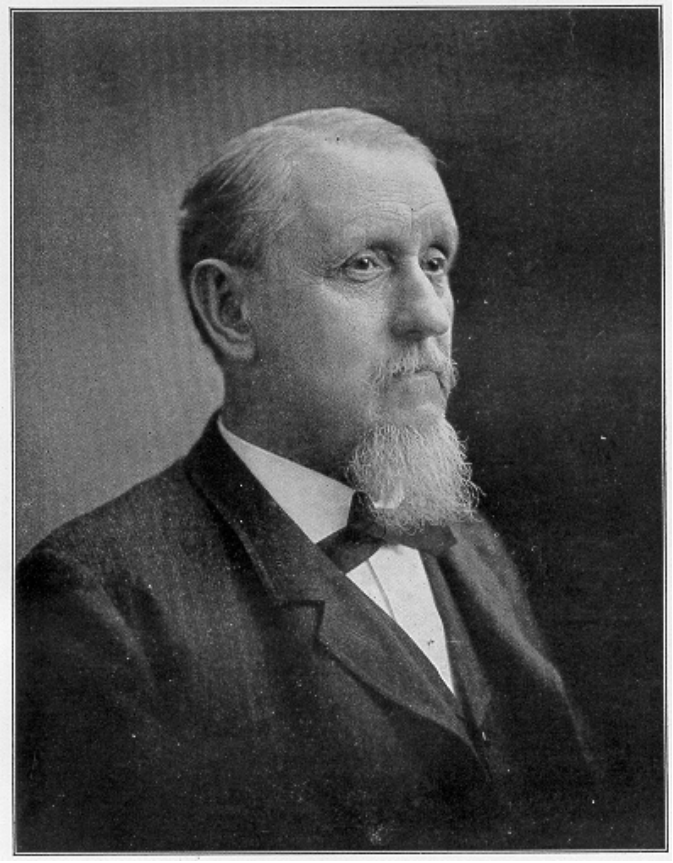

PROFESSOR WILLIAM H. PETTEE.

SEVENTH REPORT OF THE MICHIGAN ACADEMY OF SCIENCE

CONTAINING AN ACCOUNT OF THE ANNUAL MEETING

HELD AT

ANN ARBOR, MARCH 30, 31, AND APRIL 1, 1905.

PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY
CHARLES E. MARSHALL
SECRETARY

AND

WALTER G SACKETT
ASSISTANT SECRETARY

BY AUTHORITY

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TABLE OF CONTENTS.

Letter of Transmittal 1

Officers of the Michigan Academy of Science. 2

William Henry Pettee. 2

Papers Published in this Report:

President's Address, Natural Resources, Their Consumption and Conservation, by A. C. Lane. 3

On the Origin of the Sulphur Deposits at the Woolmith Quarry, Monroe Co., Mich., Edward H. Kraus 8

On the Occurrence and Distribution of Celestite Bearing Rocks, Edward H. Kraus 10

Relation of Lake Whittlesey to the Arkona Beaches, F. B. Taylor 10

Drumlin Areas in Northern Michigan, Israel C. Russell. 14

Change of Level at the West End of Lake Erie, E. L. Moseley. 14

A Study of Plants in Ravines Near Adrian, Francis L. Stearns. 15

Plant Distribution in a Small Bog, Edith E. Pettee 17

Ravines in the Vicinity of Ann Arbor, Alfred Dachnowski 19

A Study of Soils by Young Students, J. A. Jeffery 19

The Black River Section near Bessemer, W. C. Gordon 21

LETTER OF TRANSMITTAL

TO HONORABLE FRED M. WARNER, *Governor of the State of Michigan:*

SIR—I have the honor to submit herewith the Seventh Animal 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,
CHARLES E. MARSHALL,
Secretary of The Michigan Academy of Science.
Agricultural College, May 5, 1905.

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WILLIAM HENRY PETTEE.

In preparing a memorial of William Henry Pettee, for so many years a leading member of the faculty of the University of Michigan, I shall have to draw largely upon the memorials prepared by those older than I who had seen more of him.[1] My own acquaintance with him dates only from 15 years ago, when I met him (during the course of one of his tours examining high schools) in Houghton. We talked over the College of Mines in Houghton, which was then less than five years old, and his unselfish point of view struck me very strongly at the time.

In these days when temptation to originality even in error is so strong and ambition for fame as dominant among scientific men as in other walks of life and perhaps more so, it is well that we should commemorate in a way that will make his example tell upon us and upon others the life of one who valued accuracy and correctness above originality and duty above fame and who illustrated the value of broad general culture as well as special knowledge.

He was born January 13, 1838, at Newton Upper Falls, near Boston, Mass., the son of Otis and Matilda (Sliernian) Pettee, his father being a cotton manufacturer. He was not very robust and entered college at 19 years of age. He took high rank in the course which was at that time mainly made up of required work and largely classical. He delivered a Latin oration in his junior year and was graduated in 1861. He continued in connection with the University, studying in the engineering subjects in the Lawrence Scientific School, and in the college, where he was also assistant in chemistry. He took his A. M. in 1864. He was chemical assistant from 1863-65, the subject which he had elected in his junior year. He studied in Europe, mainly in Freiberg, from 1865-68, and returned to Harvard, being appointed instructor in mining in 1869 and assistant professor in 1871. He married July 8, 1874, a fellow townswoman, Sybil Anna Clarke. In 1875 he was appointed professor of mineralogy, economic geology and mining engineering at the University of Michigan, and he continued to hold this chair until his death, although the growth of the College of Mines had relieved him of some part of the duty which would naturally fall to the incumbent of this chair, and he had become editor of the University publications, confidential advisor of the Regents, secretary of the University senate, and leading member of the faculty in all University problems.

His first professional field work seems to have been in 1869 in the south part of Colorado, and from 1871 to '80 he was engaged in connection with the California State Geological Survey under J. D. Whitney. From this work came two publications, "Contributions to Barometric Hypsometry," with tables for use in California (1874—a supplement of additions was added in 1878), and the investigations of auriferous gravels, which is published as an appendix to Whitney's report. These publications are said "to show that careful examination of phenomena, weighing of evidence, and painstaking accuracy, which those best acquainted with Professor Pettee always expect in papers prepared by his hand." He edited the mining and metallurgical terms for the Standard Dictionary.

It may be that the disease of the heart, which has finally brought his earthly career to a close, checked his activity in the field, for he told me of it years ago, had been very painfully conscious of it for many years, and knew that any hour might be his last. The patient and cheerful courage with which he kept on the round of duty under these circumstances is an example to us all. He was prominent in many societies and did some of his most valuable work in that connection. He was a member of the Phi Beta Kappa, American Institute of Mining Engineers, American Association of Advancement of Science, Geological Society of America, American Philosophical Society of Philadelphia, and Michigan Academy of Science, and had held offices in many of these. In particular his association has been intimate with the Mining Engineers of whose transactions he has read the final proof critically for many years. The

qualifications for a good proof reader are very high. I often feel my deficiency in this respect. They include a good memory, sound judgment, a very wide range of exact information, patience, a zeal for accuracy, and yet the kind of a mind which will not, in looking out for commas pass unnoticed blunders of sense. It has been said that it takes a poet of the first order to translate a poet of the first order. So to read proof well requires a reader who knows more than the author of the article. In this department, Raymond writes, "He would detect a broken or inverted letter, a column of figures that did not 'add' right, a mistake in a chemical formula or algebraic equation, an incorrect reference or quotation, a blunder in a foreign tongue, or a logical absurdity, obscurity or contradiction—all with equal certainty and precision. Backed by the great library of the University of Michigan, he was absolutely indefatigable in following the trail of the smallest question involving reference, quotation, or statement by one author of the views of another. It was, indeed, a startling revelation to me that, of the passages marked by authors as quotations, he found so many which gave the quoter's notion of the meaning, instead of the exact words of the original. In this, as in all other particulars of the ethics of authorship and scholarship, Prof. Pettee was an unerring and uncompromising authority."

He was a loyal supporter of the church of his choice, and his fidelity to truth was a characteristic that impressed his colleagues. Overstatement, exaggeration, and disproportionate display would be as unfit for him dead as they were to him living, but the societies who have owned him as a member have reason to regret his departure, and when Rossiter W. Raymond speaks of his "unimpaired reason, manifold knowledge, balanced judgment, dauntless perseverance and loyal affection," he was using chosen words weighty with meaning.

A. C. LANE,
Lansing, Michigan,

[1]Science July 8, 1904, p. 58. Transactions American Institute of Mining Engineers, Biographical Notice by R. W. Raymond, 1904.

NATURAL RESOURCES, THEIR CONSUMPTION AND CONSERVATION.

A. C. LANE.

In these days of evolutionary theories and dominance of biology it has become fashionable to apply the analogies and language of biology in other fields,—for the geographer to speak of mature rivers, and youthful drainage; and the sociologist and historian to speak of society and nations as organisms. So, without going so far as to assume that are units of consciousness apart from brains, and that there is an American or Michigan consciousness (standing in somewhat the same relation to your consciousness and my consciousness as ours, it may be supposed, to the sensitiveness which may belong to each individual cell of our body), we may still accept the comparison of the nation or state to that of an organism so far as it may help us to remember and collate real facts.

The youth of a people is in reality like that of a man, full of hope, extravagant, feeling boundless resources, and inclined recklessly to squander them in attaining the objects of desire. If it is wisely guided age may bring mature judgment, more careful and conservative expenditure, and riches which are not merely in prospect but in possession, which are the fruits of useful industry and the relics and mementoes of a noble ancestry. Unwisely guided, age may bring the exhaustion of the resources thought to be boundless, with nothing worth while to show for them; and as the individual man may be found bankrupt in purse and pride, so the nation or community may suddenly find its supposedly inexhaustible supplies exhausted, the fabulous fertility of its fields failing, its hills once clad in forests naked and seamed and gashed by gullies until they remind one of the beggar's clothes whose spendthrift habits have dragged him down to like depths of destitution.

Mill[1] says that "looking on the world as not only the home of man, but as subservient in all its phenomena to the welfare of the human race, we may consider the development of any region to mean such treatment of its natural resources as will enable the land to continue to support an increasing number of inhabitants," and ventures the suggestion that "fortune hunting is inimical to development in its true sense. A fortune acquired through production or speculation can usually be made by only a few individuals and almost always entails the exhaustion of natural resources or the lowering of wages; a prosperous livelihood, on the other hand, can often be secured to a multitude without permanent impoverishment of the land."

The former statement we may consider a very fair definition of development of a country. The latter is one of those general statements which are hard to disprove, being both vague and qualified. But it suggests that there may be such a thing as improper development. Much talk and writing seems based on the theory that development is always and only good—is a good in itself. This we may fairly question. Legislation has too often been but the application of formidable locks, bolts and bars to the door of an empty stable.

[1]Hugh R. Mill, New Lands, p. 7.

It is fit, then, to consider what is the path of wisdom, what is that true development of our natural resources which scattereth and yet increaseth, and what is that development which may better be called devastation, whose scattering is not that of the seed corn which returns many fold, but that of the whirlwind and tornado? How may we best conserve our resources and how secure adequate compensation for that consumption which is necessary? These are questions in which we have an interest, as scientists studying either the face of nature or the course of history, as patriots desiring the welfare of our country, and as parents desiring to pass on unimpaired the patrimony that has come down to us.

In the first place let us note that the development of national resources does not-in all cases imply consumption. It is true that you cannot eat your cake and have it, too, but it is also true that you can use your house, that you can see your picture, and gaze at your statue, and they be none the worse for it.

Italy and Greece are wealthier today than they would have been had the marble of their statues remained in the quarries of Paros or Carrara, for the marble still in the quarry has not the value that it has piled up in the Parthenon. Every Milton who dies mute, inglorious, but who might have sung immortal verse is a loss and waste, most of course to the higher and spiritual interests of the nation, but also to the commercial interests as well. I do not know how much cash loss of trade it would be to Stratford-on-Avon had Shakespeare lived and died there without knowing letters, but I do know that the American pilgrims to the footsteps of great men gone before us leave in Italy every year hundreds of thousands of dollars.[1]

So the fact that the Republican party was born in Jackson meant many dollars to many Jackson people about a year ago. Thus a development of our natural resources which means merely turning material into more valuable, artistic shape, or surrounding it with inspiring associations—such development is pure gain and no loss, so long at least as we do not bury living prophets under the tombs of their forerunners or shackle the present with reverence for the past.

Schools and professional feeling which help the workman to become the artizan, to put individuality into his work and feel a pride in it, are thus directly helping the prosperity of the commonwealth and money spent in the production and education of men who serve mankind and whose footsteps will be gazed upon with reverence by coming generations is money well spent. Again, insofar as work of artistic value is expended upon material which is retained in the State, there is a definite increase in the wealth of the State. This accumulation of wealth may be either by the importation of art from abroad or by turning our own material into art forms. Particularly is this true of architecture and of furniture which is worthy to descend as heirlooms from father to son.[2] The accumulation within the State of Art treasures. that is to say of fine work in fitting material, is therefore a means of increasing the wealth of the State.

[1]"Last year was a record breaker, and Americans paid $35,379,050 for ocean steamship fares from New York alone. It is claimed that Americans spent four times as much as their fares while abroad, and that makes a total of $131,516,000 spent in Europe and other parts of the old world last year, by people who sailed from New York."

[2]The money spent in making dollar chairs is no permanent gain to the community. A Chippendale sofa on the other hand is worth more than ever.

In the second place I would, call attention to the resources of which there is a continuous and transitory supply in contrast to those of which there is a stock, in the use of which we are drawing on an original supply or the accumulation of generations. The farmer's windmill in using wind power is using a resource of the former class, while the use of coal is drawing on a reserve.

Farm products so far as they are due to air, water, sunshine and hard work and but mint the golden sunshine into golden grain, which is converted into golden coin, are a development of resources continuously supplied. But there is also a little ash or mineral matter which if not replaced by manure or fertilizer is a draft upon the capital of the commonwealth.

Most important perhaps of these resources in this state is the water power, which is indeed largely used, but of which, there are thousands of horse power going to waste in our streams. Any permanent, substantial dams which may help us to utilize this, as it is proposed that the power of the Huron shall be utilized, will be a permanent gain to the resources of the state. So again topographic maps which may help us to recognize this, or the work which Mr. Horton is superintending in gaining accurate knowledge of the wealth of water power, so much of which is as yet unutilized, is a direct provision for the day of exhausted coal.

Thirdly and of most interest to our theme are the resources which are wasting away in the use. As we gaze on a piece of soft coal across the cleavage we shall see dozens of alternating bright and dull bands in an inch. Each of these may represent an annual or semi-annual change of climate and a ton of coal may represent 60 tons of wood. Thus in using coal we are dissipating in a few years the accumulations of generations heaped up millions of years ago.

Now of these reserve accumulations, there is, and I cannot emphasize the fact too strongly, there is never an inexhaustible supply. People a scant half century ago used to talk of the inexhaustible supplies of pine in the Saginaw. There is now hardly a stick standing. Men prate of inexhaustible mines. The bottom of perhaps the greatest mine in the world, the Calumet & Hecla, on its conglomerate is much too visible. Of course sometimes the supplies are in a way practically inexhaustible. The salt of Michigan, if the present rate of production of two billion pounds a year is not too greatly exceeded, probably might last some two million years. Yet the consumption will increase, we know not how much, and a much less time and amount would threaten the collapse of Detroit beneath Lake Erie.

They talked only a few decades ago of inexhaustible supplies of iron ore, and yet now a pretty well posted man says there is in sight but 30 or 40 years supply of ore—that is now merchantable I presume he means. I would double that and say that at the present rate of consumption of some 23,000,000 tons a year there is probably enough (for, in fact, I think the steel trust alone owns over a billion tons of ore in Michigan and Minnesota) for 80 years' consumption. Still that is not a very long time, in the life of a nation.

One tiling must be noted in regard to this matter of exhaustion. It is rare that a resource supposed to be inexhaustible comes so sharply and entirely to an end as

the pine of the Saginaw valley (the American Lumberman says that pine is on the toboggan), or the countless herds of Buffalo of the western plains, which were sharply wiped out between 1877 and 1887, so that the buffalo coats which the street car men wore when I was a sub-freshman were a luxury of the rich when I was graduated. Usually as the cost increases it tends to cut down the consumption until a certain balance, depending upon available substitutes, is attained, and so the price slowly rises and consumption keeps on decreasing. That is the way in which our anthracite coal fields, and the British coal and iron ores are becoming exhausted. Moreover in many cases there may be both an accumulated stock and a continuous supply. For instance, it is so to a certain extent with our forests. The magnificent growth the pioneers found here was an accumulated stock. But in many countries forests, like the farmer's wood lot here, are looked to for a continuous supply. We must soon be in that case. Originally the great white pine belt extended over 400,000 square miles and there may have been 700 billion feet of it at the beginning, say in 1851. By 1901 there was but 110 billion feet, which was going at the rate of 7 billion a year. So within 10 years there will be no more white pine—it will be hemlock, jack-pine, anything. As the annual consumption in the United States is some 25 billion cubic feet, and the total forest area of the United States is some 500 million acres, from which American lumbering practice will only get 420 board feet per acre a year, it is obvious that even though we improve to the standard of the German practice of 660 board feet per annum we must still either reforest large areas or And substitutes. It is difficult to see the national economy of rushing through our timber pell-mell at a low price and then buying that of our neighbor, Canada, at a high price.

Beside stored up treasures of wood and coal the loss by extermination of any animal or plant is one which may indeed be small, but may easily be irreparable. The last survivor of those flocks of wild pigeons which once darkened the sun seems to have winged his solitary way to that bourne whence no traveller returns, which the fowler's eye may vainly strain to discern. The same thing is almost true of the wood-duck. Logging operations have absolutely cleared many a stream of trout, and it might easily be that grayling, whitefish and sturgeon would become as unknown as the wolverine in the Wolverine State. The gain or loss of all this or of preventing these exterminations I am not prepared to state. I presume in some exterminations like those of the rattlesnake and the wolf there is a distinct gain. But it is not well that we should let these exterminations of our animal neighbors go on in sheer heedlessness, but take some pains to preserve and propagate those most valuable. A great body of laws on game preservation and fish culture show that we realize something of this. Yet I venture to say that we still know far less than we might of what animals should be preserved and especially how best to do it, or which of our animal friends are being exterminated and how best to stop it. Many a well meaning action fails in its object because based on imperfect knowledge.

First, then, as regards these exhaustible resources we should know what is happening. Again we should try to make the consumption as little wasteful as possible, so that we may get the full benefit of all that is used. As we shall see, unwise action may almost force extravagance.

Thirdly we should put the produce to such good use that we may have something to show for the exhausted resources. In particular, then, we should see that so far as possible substitutes are devised and developed.

Now to illustrate the kind of knowledge we should have.

Our marl or boglime beds, which have been used as the base for cement factories have been produced in the past few thousand years, but the lake algæ and shells are still busy abstracting lime from the hard water. One thing which it would be interesting to know is how fast our marl beds are growing and how many acres of pond and bog and cubic yards of boglime a company should have, so that when they got around they could begin over again. The state might well encourage such an investigation and also see how fast it could be accumulated by the fittest plants. In the same way with our peat bogs. If peat comes to be a popular fuel, and I believe it will, it will at first be mainly on accumulated peat that we shall draw, but it will also be worth while to know how fast a bog can be made to grow and whether its growth can be stimulated by changes in water level or encouraging appropriate plants. I believe the layers showing the annual rate of increase of depth are in some bogs from an inch in depth near the top to one-twentieth of an inch at the bottom, or say 182 to 3630 cubic feet per acre per year, or between 25 and 50 tons of fuel value per acre. In this case and probably also that of the marl or boglime, it may be only the accumulated stock that can practically be counted as wealth. I would suggest it as a good reason for the commonwealth's economic policy that scientific research be endowed on just these grounds, that when our present coal mines are exhausted we may know where most readily to find new, and when these in turn are but hollow voids some inventor shall have found a storage battery that will turn Ariel from a tricksy sprite to a mighty genius of work and make the windmill as much a source of power as the water wheel.

A Frenchman has recently suggested setting a coal mine on fire and pumping down just enough air to make water gas and then burning this gas as it comes to the surface. If this idea proves feasible it would add untold millions to the wealth of this state in seams which it would not now pay to burn. But in any case by the time our earlier sources of power, lumber waste and coal, are exhausted, we may discover oil and gas, or use our water powers to develop electric heat or grow our own fuel either as four-foot wood or as peat, whichever shall be proven by scientific experiment to be the most economical and be ready with our streams already

dammed and copper cables covering the land to furnish more power from water than we now use from coal.

So, again, little by little the unfertilized farm will become less fertile, for in spite of all the care and skill of the Michigan farmer the wheat product per acre of the lower four tiers of counties of Michigan does not bear the same ratio to that of the state that it once did.[1] It is well worth while, therefore, to see, as they do at the Agricultural College, that we are getting our money's worth in buying fertilizer to replace the fertility. It should be worth while to see that we do not squander valuable potash salts in making table salt, or burning lumber waste, etc.

[1]Average Yield per Acre of Wheat in Michigan.

Year.	State.	Southern four tiers of counties.	Excess.
1876–1880	15.4	17.7	2.3
1881–1885	16.6	16.9	0.3
1886–1890	15.6	15.9	0.3
1891–1895	16.0	16.2	0.2
1895–1900	13.4	13.2	— 0.2

Again, as our forests depart, not only should we cherish what is left, but with the proceeds, before we are left naked, poor and desolate, we should plan to develop substitutes: tile and slate for shingle; cement, sand-brick and stone for building; stone cement and steel bridges for wooden; and paving brick and macadam for cedar block and corduroy. The Bureau of Chemistry of the Department of Agriculture at Washington is hard at work seeking for fibres which may replace the wood pulp.

We may hope that by the time our present iron ores are becoming exhausted our scientific chemists will have found some economic method of smelting leaner ores, or, better yet, of handling that vast bulk of iron ore, of which we now know, that is made refractory by only a few per cent of titanium. Our geologists may have found for us new ranges or extensions of the old ones under the Paleozoic mantle.[1] So, for instance, we might appropriately tax a foreign corporation like the fish trust, catching or buying Michigan fish, for the purpose of supporting our fish commission, which studies our fish and stocks our rivers and lakes, which are not producing a tithe of the fish food they might.

Moreover, as we have said, we should see that the necessary consumption is as little wasteful as possible. Legislation which is such that “we skin through as fast as we can and then throw the land back on the state" is not wise legislation. I am well aware that there are two parties in politics and in economics as to whether the state should hold for itself these natural resources. But if it be granted that the state should put these in the hands of individuals to exploit it is certainly short sighted to then so legislate in the hope of getting" back again "unearned increments" by taxation that the individual is tempted or even forced to rush through the development, squandering a large proportion of the resources in order to get the utmost possible returns to himself. It is very easy by legislation to accomplish just this result by taxing not according to the income or return, but according to some fixed valuation, especially if excessive, so that the problem for the individual is to get the utmost income in the shortest time and avoid the most taxes.

In the same way the policy of taxation which leads those with accumulated property to leave the State and transfer the money which they may have made from its resources to some other clime, and their interests to other institutions, will not correct any error which may be supposed to have been made in allowing them to accumulate that wealth in the first place.

It is often proposed to correct and control the excessive accumulation of wealth and the power of wealth by competition but it must be remembered that competition is a most potent source of waste. The different iron ores are used together to produce a maximum amount of iron from a minimum amount of iron ore, because they are all owned by the same parties, regardless of the fact that some of the ores can be produced much more cheaply than others. But if the ore belonged to different parties and there were free and unrestricted competition the most cheaply produced ore would crowd the others for a time entirely from the market and would cause a decay of the town supported by their development. I do not think that anyone would consider this desirable, and certainly from the point of view of the geologist there would be a waste of resources.

[1]Lines of magnetic attraction show that the iron ranges extend down to Green Bay under a thickness of not over 1 000 feet of Paleozoic mantle.

It is lucky for Michigan that the iron ore of Lake Superior is held by a comparatively few strong corporations, the U. S. Steel Co. having say a billion tons of the Mesabi range and many million tons of the older range. The Mesabi ore is a mere mass of varicolored dirt. I saw live forties last summer said to contain 200,000,000 tons of ore. All that has to be done is to run in trains of ore cars and load it on by steam shovels, after once the layer of clay till, etc., overhead is removed. The huge, yawning, red chasms thus left, when wreathed in the smoke of puffing locomotives and laboring steam shovels, present a volcanic and truly infernal picture. In time some of them will be 400 feet deep) and over. The ore, too, is largely of the highest grade. What could any ordinary iron mines do in competition with such, especially those of Michigan where the miners have now all disappeared under ground?

Fortunately, however, it has been found that in the draft of the blast furnace in which these ores are reduced to iron, a good part of this light powdery ore is liable to be blown out if not held down by something more substantial. Moreover a certain amount of some flux must be added to aid the flow of iron, and the silica of some of our Michigan harder ores poorer in iron is admirably adapted to that end. And as the same interests own properties in both States they prefer rather than to let their Michigan properties go to rack and ruin to use a moderate amount of that ore and save wasting their Mesabi ore, even if thereby it is not produced quite as cheaply at the moment. They fix the price and in the long run it will be doubtless better for the community and

corporation. More iron will be made with less work, by mining the high grade and low grade ores together, than there would were the high grade ore first run and wasted and then the low grade ore developed. The same thing is true regarding coal. In an era of unrestricted competition only the choicest portions of the best seams would be put on the market provided, as is true, there is a possibility of producing more coal than can be consumed. Customs such as that of paying royalty only on the coal mined may favor wastefulness. If the royalty were per acre foot, it would pay to mine more closely, as I have said in my report on coal. Thus it is for the State's interest that coal royalties should be per ton on coal in the ground, not per ton of coal hoisted. This is practicable and done in some coal fields. In the case of iron ore, too, much property has changed hands on- the basis of the ore in the ground as shown by drilling. In the same way in Indiana it has been found necessary to pass laws restricting the waste of gas or oil because in so many cases it was cheaper for the individual to save the one and waste the other regardless of the effect upon the resources of the State or his neighbor's wells. It would seem therefore that in relying upon competition as a cure for the ills of the body politic or in attempting taxation of the "unearned increment" we should not fail to consider carefully the effect of these remedies upon the development or conservation of the natural resources of the State which, once squandered, no financial or political ledgerdemain can restore.

I know that the questions here raised are difficult ones and I know no panacea for all the wastes of the body politic. I might indeed suggest that it seems to me that municipal or State ownership is too often treated as of necessity synonymous with municipal and State operation and exploration. The Boston subway is a good illustration of public ownership and private operation, which apparently works better there than would any other plan just now. I may perhaps remind you, too, that in Mexico all mining is under a system of State leases, and in Canada lumbering. In this commonwealth the policy has in general been for the State to divest itself of the title to its lands, with their resources, even though they could be sold only for a song, and were mainly useful, to be cut up into lots to be given away with "free chickens." thus to make work and fees in the process of title registering and tax collecting. Even our State institutions of learning have largely divested themselves of their landed wealth. Would not in many cases a lease for fifty years or longer have been exactly as well? It is a fair question, how far it is wise for a community to let its wealth go permanently out of its own hands, and in particular into the hands of nonresidents. Non-resident property owners have been a source of friction ever since the days of the nobleman who let out his vineyard to husbandman and went into a far country. Harvard University years ago, instead of selling Boston real estate outright, had a policy of letting it on a 99 year lease. And of late every now and then a piece of property, like the Adams house, worth a couple of hundred thousand reverts, and is a very welcome addition to their unrestricted funds. It seems to me well worth while to consider whether it would not have been, and even now be, a wise policy for the State and its land owning institutions in regard to land not best suited for homesteads, to have leased the lands for a term of years rather than deeded the property outright. Certainly a lot of land would have come back to them, and kept off that maelstrom of useless expense,—the delinquent tax list. While this I would merely suggest, what I would urge is more careful and intelligent consideration of our waning natural resources, so that before they are gone we may develop substitute products and replacing industries, and that their proceeds may go in part into permanent improvements, and additions to the wealth of the State, stone roads replacing plank roads, stone or cement bridges wooden bridges, stone or cement dams wooden dams.

But of all the wealth that Michigan has possessed I ask anyone to find any that has been better spent for the permanent wealth of the community than that which has been spent on educational institutions. They produce intelligent citizens. They draw into the State an intelligent public which spend much money at the time. Many of them stay here to help build up the State. Their buildings and equipment will be more and more Meccas and permanent objects of interest and attraction and resort. Their scientific researches will help to develop, to save, and to replace our natural resources.

I can picture in my mind two fortunes, and they will be but composite photographs drawn from life. The one is built upon a reckless cutting out of the choicest of lumber, none but the best taken, the brush left around, and fired either purposely or fraudulently to conceal theft. In the path of the first fires is left either a tangled mass of worthless trash, overgrown with bushes and fireweed, ready fuel for a of conflagrations that sweep through from time to time, or a plain covered with sweet fern and goldenrod, used by Chicago speculators to defraud the settlers who from time to time try to make a livelihood from it.

There are here three wastes, the half crop of timber later burned, the land left in a useless condition, and labor wasted in trying to make it useful.

The logs thus gathered are driven to the mill by a crew of loose livers hard earned wages are largely scattered to the dive and brothel in a few weeks. The saw mills devour them and circular saws rip a wide swath of saw dust waste at each cut; piles of slabs, saw dust, and of every description are transported in a continuous stream to an ever burning fire whose pillar of cloud by day and fire by night be-the presence not of Jehovah but of the demon of destruction. The timber itself is shipped east to build up the fame of Michigan pine and the money thus acquired by one who keeps on making money because he does not know what else to do, is squandered by his heirs who by themselves or by those whom they purchase as husbands, scatter it to scandalize two continents.

The forest, the accumulation of generations, and of ages of sunshine, rain and dew, is gone, and there is less than nothing to show for it. This is criminal waste.

Now let us paint a brighter picture. Into the forest go a lot of sturdy pioneers, such as Ralph Connor loves to picture, bent on caring for themselves and their children. The instructions are to cut every top, and every thing is gathered up, even old half burned logs. Whatever is not otherwise used is used for fuel in making salt, but all that can, be used down to stuff that will only make lath or matches or toothpicks is saved and pains are taken to make even the narrow band saw cut as narrow as may be. The land is left ready, if it is good enough, for one of those same sturdy pioneers to take hold of and make a farm that will be the stay of his old age, and the homestead of his children. That best fitted to remain forest returns once more to the State to be reforested.

The lumber goes where it is most needed, but part of it into buildings within the State, of permanent artistic value—a permanent pride and landmark, like the capitol. The fortune thus acquired is expended perhaps in part in reforesting those parts of the tract that are better suited for forest growth than for anything else, and in their fire protection, but those lands hardly worth paying taxes on are deeded to some State institution to which after some years they will be of great value, while in the meantime they are kept off delinquent tax rolls.

Another part of this fortune is employed in permanent improvements, roads and railroads, and in buildings which are a permanent addition to the beauty of the State as well as a memorial of the man who reared them. Another part goes on starting industries and providing education which will open fields of valuable employment and keep alive the town where the fortune is made when lumbering ceases to be the all sustaining occupation.

A part may be employed in exploring for coal, developing peat or water power, drilling for oil. mineral water or other resources to replace those that are vanishing.

The forest then is not wholly gone, and in the place of the part taken are fertile farms, with happy homes, noble buildings, intelligent people and varied industries, and the State is wealthier than ever.

The one picture is as true as the other (Mr. Hackley's fortune illustrates many of the brighter items) though they are put together like one of Thompson Seton's stories, but I hope and think that the brighter picture is the one becoming more true. For this let us all strive as citizens not merely of the kingdom of science and the republic of letters but of the commonwealth of Michigan.

ON THE ORIGIN OF THE SULPHUR DEPOSITS AT THE WOOLMITH QUARRY, MONROE COUNTY. MICH.

EDWARD H. KRAUS.

From the mineralogical standpoint, the Woolmith quarry, half way between Scofield and Maybee, Monroe County, is very interesting on account of the occurrence of a very considerable amount of native sulphur, accompanied by its usual associates, celestite, calcite and sometimes gypsum. It is not necessary to discuss at this time at any great length the geological conditions at this locality, for they are admirably set forth by Sherzer in his "Geological Report on Monroe County."[1]

The rocks at this quarry are for the most part dolomites, sometimes, however, quite siliceous, and have been assigned to the Monroe series. Many of the strata contain a relatively large percentage of bituminous matter. It is also important to state that the strata at or near the surface are usually quite compact and vary much in color—from gray to brown—and are more or less blotched or streaked. These compact layers are characterized by an unusually high specific gravity. Inasmuch as the rock is not homogeneous, different values were obtained. They varied from 2.80 to 3.45. The specific gravity of a normal dolomite ought to be 2.80 to 2.90. This high specific gravity must hence, be considered as indicative of the presence of some mineral, possessing quite a high specific gravity, disseminated throughout the rock.

As we descend into the quarry the rocks become more porous and cavernous. It is in these layers with cavities, ranging from a few inches up to a foot or more in diameter, that the native sulphur with the associates, indicated above, is found. The occurrence of these minerals is clearly one of secondary formation.

The rocks near the surface, although compact where they have been protected, show, when exposed, the characteristic structure of leached celestite-bearing rocks which are quite common in the rocks of this series or its equivalent.[2] This, together with the high specific gravity, already referred to, would suggest the presence of celestite. In order to determine the presence of celestite and also its probable percentage, an analysis of the uppermost layer, characterized by Sherzer as Bed A, was made by Mr. W. F. Hunt, assistant in mineralogy in the University of Michigan.

As already indicated, the rock is by no means homogeneous, and hence, in order to obtain as near as possible the average composition of the same, many chips were taken from a specimen of approximately the following dimensions, 4x5x6 inches. The specific gravity of most of the chips was determined and the following are some of the values obtained: 2.80, 2.87, 2.98, 3.17, 3.33, 3.45.

[1]W. H. Sherzer, "Geological Report on Monroe county," Geological Survey of Michigan, 1900, 75.

[2]E. H. Kraus, "The occurrence of celestite near Syracuse, N. Y., etc.," Amercan Journal of Science, xviii, 30-39, 1904. Also "Occurrence and Distribution of celestite-bearing rocks," ibid, xix, 286-293, 1905.

The methods pursued in this and the following analysis were those recommended by Hillebrand[1] in his treatises on rock analyses. Knowing that much would depend upon the separation of the earth alkalies, the utmost care was exercised in their determination. Their precipitates were in every

instance tested spectroscopically and, if necessary, the extraction repeated until in each case they could be considered free from contamination. We may, therefore, regard the results obtained as very accurate. They are as follows:

	Per cent.	Molecular ratio.
SiO_2	0.58	
Al_2O_3 / Fe_2O_3	0.37	
CaO	25.18	.448840
MgO	18.11	.448710
BaO	0.33	.000848
SrO	7.86	.075870
Na_2O	0.11	
K_2O	0.05	
P_2O_5	0.02	
Cl	0.04	
CO_2	39.55	.89886
SO_3	6.33	.079067
Organic Matter	0.92	
H_2S	Trace	
	99.25	

The percentages of the oxides of calcium, magnesium, strontium and barium, together with the carbon dioxide and sulphur trioxide, are important. It is at once noticeable that the amounts of strontium oxide and sulphur trioxide are relatively high. A comparison of the combined molecular ratios of the oxides of calcium and magnesium with that of the carbon dioxide,

$$\left\{\begin{matrix} CaO & (.44884) \\ MgO & (.44871) \end{matrix}\right. : CO_2 (.89886) = 1:1.0014,$$

shows that the rock is a dolomite, and in fact a normal dolomite. We, thus, have quite conclusive evidence that all of the calcium oxide is, doubtlessly, present as a carbonate and not in part as a sulphate.

The unusually large amounts of strontium oxide and sulphur trioxide are extremely interesting. If we consider the small amount of barium oxide present as isomorphous with the srtontium oxide, we obtain the following proportion:

$$\left\{\begin{matrix} SrO & (.075870) \\ BaO & (.000848) \end{matrix}\right. : SO_3 (.079067) = 1:1.0306.$$

These values indicate that the sulphur trioxide is combined with the oxides of strontium and barium, and hence, evidence is at hand that the mineral celestite is present in this uppermost stratum to the extent of 14.32 per cent. The results of the analysis are, therefore, in harmony with what has already been said concerning the structure, specific gravity and so forth, thus indicating that the celestite is present in a disseminated condition, doubtlessly, of primary origin. The very small amount of the combined oxides of aluminium and iron, namely 0.37 per cent, would preclude any appreciable quantity of pyrite or marcasite being present. It is also significant, as will be seen later, that organic matter and a trace of hydrogen sulphide were noted.

In the lower strata as already said, the celestite is found lining the cracks and cavities, and is, of course, of secondary origin.2 It is with these secondary occurrences of celestite that the native sulphur is found.

Sherzer[3] in discussing the origin of the sulphur at this locality rightly refers the same to the hydrogen sulphide, which is to be observed in considerable quantities not only in the water at this quarry but also in the majority of the wells of that section of the county. Sherzer thought that the hydrogen, sulphide might be due to the decomposition of pyrite and marcasite, which are supposed to be present in considerable quantities.

[1]W. F. Hillebrand, Bulletins 148, and 176, U. S. Geological Survey.

[2]E. H. Kraus, "Occurrence and Distribution of Celestite-bearing Rocks," American Journal of Science, XIX, 290, 1905.

[3]W. H. Sherzer, "Geological Report on Monroe County," 212, 213, 1900. Also, American Journal of Science 3rd series. L. 246-248, 1895.

The analysis of the rock from Bed A, however, shows clearly that if the sulphides of iron are present in the uppermost layers, they must be present in amounts which are almost insignificant when compared with that of the celestite. It is also of vast importance to call attention to the fact that, when the rocks of the various layers in this quarry are treated with dilute acid, or even boiled with water, hydrogen sulphide is liberated. To be sure, in some instances the amount is very small but, nevertheless, even a trace is of great import, indicating that a soluble sulphide, no doubt, strontium sulphide, is present. We must, therefore, consider the theory that the decomposition of pyrite or marcasite by the formation and subsequent oxidation of hydrogen sulphide has given rise to the native sulphur at this quarry as untenable.

However, when we consider, first, that the uppermost strata contain about 14 per cent of strontium sulphate, which is quite soluble in water and hence easily transported to the lower layers by the descending waters, and second, that these and the lower strata contain considerable organic matter, and third, that there is only a negligible amount of iron present, and fourth, that hydrogen sulphide is liberated when the rock is treated with acid, it seems evident that the celestite, present in a disseminated condition and which has by the action of the organic matter become partially reduced to the sulphide, must be considered as the source of the hydrogen sulphide.

Hence, if the foregoing statements be true, an analysis of the rock from the more porous and cavernous layers, the cavities of which contain celestite and sulphur, ought to show not only the presence of strontium as a sulphate but also as a sulphide, which would be indicated in the analysis as sulphur trioxide and hydrogen sulphide, respectively.

The following analysis was also made by W. F. Hunt.

	Per cent.	Molecular ratio.
SiO_2	20.14	
Fe_2O_3 Al_2O_3	0.86	
CaO	19.56	.3493
MgO	15.32	.3795
SrO	0.66	.0063706
BaO	0.07	.0004565
H_2S	0.02	.000587
SO_3	0.56	.006994
CO_2	31.94	.7259
Na_2O	0.09	
K_2O	0.07	
Cl	0.03	
Organic[1] matter	10.68	
	100.00	

The sulphur trioxide represents the total amount of sulphur. The hydrogen sulphide was determined directly by liberation with hydrochloric acid, absorbed in potassium hydroxide, acidified and titrated with N-100 iodine.

The silica is present, no doubt, as free silica. The value of the molecular ratios of the oxides of calcium and magnesium, as also that of the carbon dioxide, give rise to the following proportion:

$$\left\{\begin{matrix} CaO & (.3493) \\ MgO & (.3795) \end{matrix}\right. : CO_2 (.7259) = 1.004:1.$$

Hence, this rock may be considered a siliceous dolomite. The sulphur trioxide and hydrogen sulphide indicate that the strontium is present both as the sulphate and sulphide. In this connection, we note that if the hydrogen sulphide be considered as having been derived from strontium sulphide, and further, if that amount of strontium, which is necessary to unite with the sulphur—equivalent of 0.02 per cent hydrogen

sulphide[2]—to form strontium sulphide, be deducted from the value of strontium oxide, given in the analysis the following relationship between the molecular ratios of the strontium oxide and sulphur, trioxide, actually present, is revealed.

$$\left\{\begin{matrix}\mathrm{SrO}\\ \mathrm{BaO}\end{matrix}\right. : (.0061741) : \mathrm{SO}_3\ (.005616) = 1.099 : 1.$$

[1]By difference.

[2]Determinations from other portions of this same layer showed as much as 0.12 per cent hydrogen sulphide. The analysis was, however, not complete and, hence, is not given.

These values are so close that we must consider this evidence in support of the above theory as very conclusive, namely, that the celestite, as a source of the sulphur, is partially reduced to strontium sulphide, which, when acted upon by an acid and even by water under some conditions will liberate hydrogen sulphide. Oxidation of the hydrogen sulphide will, of course, then give rise to the sulphur. That the sulphur should be associated with celestite is, hence, self evident.

The enormous deposits of sulphur at Girgenti and vicinity on the Island of Sicily have been explained by some in a manner analogous to the above, namely, by the reduction of gypsum ($CaSO_4$, 2 H_2O) to the sulphide, and the liberation and subsequent oxidation of hydrogen [1 2] sulphide.

Although the evidence at hand, thus far, seems ample to support the theory advanced, this paper must be considered as merely a preliminary report. The investigations are continued.

Mineralogical Laboratory,
University of Michigan.

[1]Compare Bischof, Chemische Geology.

[2]R. Braims, Chemische Mineralogie, 1896, 384, 389, also, J. F. Kemp, The Mineral Industry, 1893, 585.

ON THE OCCURRENCE AND DISTRIBUTION OF CELESTITE BEARING ROCKS.

EDWARD H. KRAUS.

[Abstract]

The study of the rocks—shales and dolomitic limestones—of the upper portion of the Salina epoch in Central New York shows that celestite occurs quite widely disseminated throughout them (1) in the form of well developed crystals and (2) in small circular spots. The celestite was no doubt deposited simultaneously with the rock material. The rocks on the Island of Put-In-Bay, Lake Erie, and in southern Michigan, especially those at the Maybee quarry, Monroe Co., show a similar occurrence of celestite. When celestite-bearing rocks are leached by the action of circulating water the celestite passes quite readily into solution and the rock then assumes a porous character; in this manner the so-called "vermicular limestones" of New York and also the "gashed" and "acicular" dolomites of Michigan may be explained. Such celestite rocks are also the source of the large deposits of celestite which are so abundant in the islands of Lake Erie—especially Put-In-Bay—and at the Maybee quarry, Monroe Co., Mich.

The paper has been-printed in full in the American Journal of Science xviii, 1904, 30-39; xix, 1905, 286-293.—Mineralogical Laboratory, University of Michigan.

RELATION OF LAKE WHITTLESEY TO THE ARKONA BEACHES.*

BY P. B. TAYLOR.

The studies of 1904 on the glacial drift and lake deposits of southeastern Michigan have shown that the history of the glacial lakes has been more complex than supposed. It has been the belief hitherto that all the principal changes of the glacial waters in the Erie and Huron basins were changes to lower levels, produced in each case by the uncovering of a new and lower point of discharge by the retreating ice sheet. It has been found that in one case, at least, the order of change was reversed. The ice re-advanced, closing an outlet which had served for a considerable time, and raised the level of the lake so as to submerge beaches which had been made at lower levels. Indeed, significant evidence was found for three such episodes, and there may have been more. One of these episodes is established by evidence so abundant and clear that its reality seems a matter of entire certainty. It is of this one especially that the present paper gives an account.

*Published by permission of Professor T. C. Chamberlin. A more extended account will appear in the Journal of Geology.

Lake Maumee was the earliest and highest of the glacial lakes in the Erie-Huron basin. Thus far, two stages have been recognized for this lake. They stood at different levels and had different outlets. During its first stage the lake lay mostly in northwestern Ohio, with an arm running up to Adrian, Michigan, and its western point projecting into Indiana. Its outlet was through the city of Fort Wayne to the Wabash and Mississippi rivers. At the second stage the hike was much the same, except that it reached considerably farther east and northeast. It also stood ten to twenty-five feet lower and had its outlet near Imlay, Michigan, and thence westward by way of the Flint and Grand River valleys. The beaches marking the two stages are known as the Upper and Lower Maumee beaches. They are both of such character as makes it appear quite certain that neither of them has been modified by submergence since it was made. In its last phase the outlet of Lower Lake Maumee emptied at Flushing into Early Lake Saginaw, which in turn discharged through the Grand River channel and Lake Chicago to the Mississippi river.

After Lower Lake Maumee had endured for a considerable time there came a change which caused the waters to fall with relative suddenness to a lower level. It is with this event that the present account begins. It has been supposed hitherto that at this time the waters fell to the level of the Belmore beach of Lake Whittlesey, which is the first strongly developed shore line below the Lower Maumee. But it has been found that the waters fell first to the Arkona beaches, which are below the Belmore, and then after pausing for a considerable time at each of the three or four Arkona beaches in descending order, the waters were then quickly raised from the lowest Arkona to the Belmore level. In this change the lake level was raised 44 to 45

feet, and in this new position the waters, stood for a relatively long time with only slight changes of level. The Belmore is one of the most prominent of the old beaches of the lake region, and during all the time that it was being formed—an interval which covered the whole period of Lake Whittlesey's existence— the Arkona beach ridges were submerged under its waters.

Lake Whittlesey was a very large lake. The expanse of its surface was about twice that of present Lake Erie. It reached from the Indiana-Ohio state line on the Maumee river to Marilla in western New York, twenty miles east of Buffalo, and from near Port Huron, Michigan, to Ottawa and Norwalk, Ohio, and to Komoko and Brantford in Ontario. Storm waves on a lake of this size would be expected to do effective work and to disturb the water to a considerable depth. It would be expected that beach ridges of gravel submerged under such waters twenty-five to forty-five feet would be much modified. And such is the fact. The shores of Lake Whittlesey which were exposed to a wide sweep of water, affording opportunity for powerful wave action, extended, within the boundaries of Michigan, from Spring Hill, a small hamlet fourteen miles northwest of Fort Huron, to the Ohio line in the southeast corner of Lenawee county. An arm of this lake also extended north from Spring Hill fifty miles to Ubly, which is at the head of its outlet. But this extension was only a long, shallow, narrow bay, less than three and a half miles wide at its mouth east of Spring Hill. The site of this bay is the present valley of Black river.

During the time of Lake Whittlesey the front of the ice sheet rested on the Port Huron moraine which was then being built. This moraine is a great ridge of clay hills extending from the north bank of Black river six miles west of Port Huron northward and northwestward along the east side of the river into Huron county, where it turns to the southwest past Cass City and Caro to Yassar. Between these points it is landlaid and is a rugged, prominent feature. South of Port Huron it is waterlaid and is low and flat. It crosses the St. Clair river into Canada one mile above the village of St. Clair. From Vassar westward it is also water-laid and passes through the city of Saginaw. While Lake Whittlesey filled the Erie-Huron basin in front of the Huron ice lobe the Saginaw valley in front of the Saginaw ice lobe was also filled with another glacial lake known as Later Lake Saginaw. The outlet of this last lake was westward through the Grand River valley. These two lakes existed at the same time-and the overflow from Lake Whittlesey entered Later Lake Saginaw and made a large channel about eighteen miles long running southwest from Ubly to Cass City, descending in this distance, as levels are now, about fifty feet. But the land has been tilted up at the north a little since then, so that the descent at that time was probably about one-third less.

The existence of Lake Whittlesey was wholly dependent upon the presence of the ice sheet as a retaining barrier or dam. The ice sheet was a solid, rock-like mass filling the whole bed of Lake Huron and part of the Saginaw valley, its front resting all along on the Port Huron moraine. About five miles north of Ubly the surface of the thumb begins to fall away northward to Lake Huron, descending about two hundred feet in eighteen miles. If the ice sheet had not existed as supposed, or if its front had stood a few miles farther north, there would have been nothing to keep Lake Whittlesey up to its level. Its waters would have found free passage around the end of the thumb at the level of Later Lake Saginaw, forming a strait between the waters on its two sides. These facts and relations were clearly made out in 1896.*

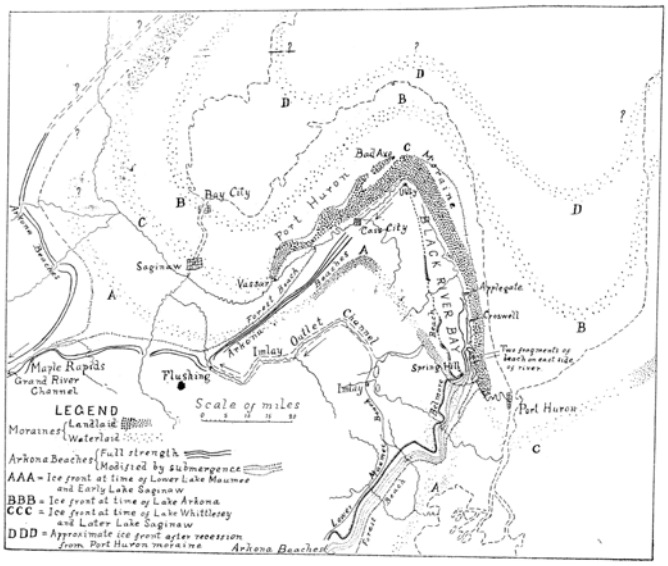
The studies of 1904 brought out further facts bearing on the history of Lake Whittlesey. Since it was discovered and named by Spencer about eighteen years ago, the next beach below the Belmore has been known as the Arkona beach. It has generally been described as a faint and broken shore line. More recently Prof. W. H. Sherzer of Ypsilanti found it in Monroe and Wayne counties with the same characters, but represented by two ridges. It was found last season that in a certain favorable locality this beach presents three well formed ridges with a fourth fainter one above, possibly belonging to the same series. The interval between the three strong ones is fifteen to eighteen feet, the middle one lying a little above the mean.

*"Correlation of Erie-Huron beaches with outlets and moraines in Southeastern Michigan." Bulletin Geological Society of America, Vol. 8, 1896. See also, "The great ice-dams of Lakes Maumee, Whittlesey and Warren." American Geologist, Vol. XXIV. July, 1899.

The Arkona beaches were found to sustain a remarkable relation to lake Whittlesey. to the Port Huron moraine and to the Saginaw valley. Briefly, the evidences and relations are as follows:

(1) From Spring Hill southwest to the Ohio line, where they were exposed to the full sweep of waves across the broadest part of Lake Whittlesey, the Arkona beaches are very faint and fragmentary. They are nearly always gravelly, but their relief is so slight that in many parts they can scarcely be called ridges, but are merely gravel belts running across the country. Usually they are not more than two to three feet high.

But besides their low relief, these beaches show another significant peculiarity. The soils which they make are not the loose, light soils which are generally found on beach ridges. They contain a considerable amount of clay which acts as an agent of cementation, and makes them stiller and more firm than ordinary beach soils. There are several deltas associated with the Arkona beaches, that of the Huron river below Ypsilanti being one of the largest. These show the same effect of stiffening of the soil by infiltration of clay. Both of these characters indicate modification by submergence. The beach ridges were almost washed away by the heavy seas that passed over them; their crests were lowered and the hollows between them and along their sides were partly filled. On the other hand, in times of quiet after storms the clay in the muddy water settled into the interstices of the gravel, making soils of the quality described.



EXPLANATION OF MAP.

The accompanying map is largely diagramatic, many details being omitted. The lakes, with their shore lines and outlets, were different for each position of the ice front. The map may be best understood by noting the lake conditions associated with each of the several resting places of the ice front in the order of their occurrence.

(1) When the ice front rested on AAA, it held two lakes in front of it. In the Erie-Huron basin was Lower Lake Maumee with the Lower Maumee beach as its shore line. Only the northern extremity of this lake is shown on the map. Its outlet was west through the Imlay channel to Early Lake Saginaw at Flushing, the outlet of the latter lake being southwest through the Grand River channel to Lake Chicago and the Mississippi river. Faint, fragmentary beaches of this lake were found between Flushing and Maple Rapids a, little above the level of the Arkona beaches.

(2) From AAA the ice front retreated to BBB. This position marks the approximate place of the western ice boundary of Lake Arkona, its eastern ice boundary being in western New York and probably across the west end of Lake Ontario. The Arkona beaches modified by submergence are shown on the map, extending from the lower edge up to Spring Hill and thence in full strength northward to Croswell and Applegate. Farther towards the northwest they are overridden by the Port Huron moraine, passing probably a little south of Ubly and thence southwest to Cass City. A few miles southwest of the latter place they reappear in full strength running southwest to Flushing, west to Maple Rapids and thence north and northwest to an intersection with the Port Huron moraine. A strait several miles wide connected the waters on the east side of the thumb with those west of it, where the outlet was westward through the Grand River channel.

(3) From BBB the ice front re-advanced to CCC (the Port Huron moraine). By this advance the ice closed the strait around the thumb and raised the level of the waters on the east side about 45 feet. The lower right hand corner of the map shows a part of Lake Whittlesey. This lake lay south of CCC with the Belmore beach as its land shore to the west and Black River bay extending northward to Ubly, where the outlet river passed southwest to Cass City. At this place the outlet entered Later Lake Saginaw which was also held in front of the Port Huron moraine and had its outlet west through the Grand River channel. The water of this lake appears to have stood at the level of the lowest Arkona ridge, for no shore line representing it independently has been found.

(4) From CCC the ice front retreated to a position not observed within the area of the map, but shown conjecturally at DDD. With this movement another similar oscillation of lake level was inaugurated, but it is not described in this paper.

(2) Spring Hill is on a spit of the Belmore beach at the entrance to Black River valley. East from Spring Hill to the crest of the moraine east of Black river is a distance of about three and a half miles. The long bay which lay to the north at that time may be called Black River bay. The Arkona beaches show their modified, low relief up to the mouth of this bay. But to the north, where they lay on the floor of the bay, they grow rapidly stronger with full relief and lighter soils, like other beach ridges which have not been modified by submergence. In the bay area they average ten to twelve feet in height. The lower ridge may be traced six and a half miles north from the road running east from Spring Hill. In the last two miles this ridge is cut away by the river in four places. Two fragments of it occur on the east side of Black river, the first one being about forty rods long and the second about twice this long. A third short fragment farther up the valley is on the west side of the river. Both of the fragments on the east side are in actual contact with the front of the Port Huron moraine. Its foot rests directly against the east side or face of the beach ridge in both cases. Within ten paces one may step from the loose gravelly soil of the beach ridge to the hard, stony clay soil of the moraine. These fragments of the beach are developed in full strength and, contrary to reasonable expectation, bear no appreciable amount of outwash, although the moraine is so close and rises to the height of sixty feet or more in less than half a mile to the east.

The middle ridge runs fourteen and a half miles north from the Spring Hill road and the upper ridge seventeen and a half miles. Both keep their full strength to the end and show no modification due to submergence. Both are finally lost by being buried under sandy outwash from the moraine, the middle ridge at a point one mile northwest of Croswell and the upper ridge one and a half miles south of Applegate.

The occurrence of strong beaches in the bottom of a valley facing a great morainic ridge so close to them, one of them being; in actual contact with it, is a very unusual arrangement. In their present relations there is no open lowland or basin in front in which waves could have gathered to form beaches, for the moraine rises to higher levels than they do.

There appears to be but one explanation. Neither the moraine nor the ice which made it were there when the beaches were being built. Instead, there must have been a wide expanse of open water in front, the ice front at that time being many miles away to the north and northeast. The remarkable preservation of the beaches north of Spring Hill appears to be due to the fact that they were submerged in a shallow bay which had a narrow mouth and which on this account protected them from the heavy seas which effected the same ridges so greatly in the open lake area south of Spring Hill. It was a re-advance of the ice after the Arkona beaches had been made that brought the moraine into the place where we now find it, close in front of the beaches, and

the same re-advance brought Lake Whittlesey into existence after the Arkona beaches had been formed. The result was that the Arkona beaches were submerged under Lake Whittlesey, and while they were almost destroyed in the area south of Spring Hill, they were protected and preserved in the Black River valley.

(3) In the Saginaw valley certain strong, gravelly beach ridges, usually two or three close together, have long been a puzzle as to their identity. Spencer thought they belonged to his Ridgeway beach which is now called the Belmore. Later, they were thought to belong to the Forest beach, and still later they were called the Saginaw beaches, and were supposed to belong to Later Lake Saginaw alone. But last year's work shows that they are in reality the Arkona beaches in an area where they have not been submerged or modified in any way. Their position next above the Forest beach confirms this identification. These ridges in the Saginaw valley are composed of gravel, are strongly developed and are in every way fully comparable with the unmodified Arkona ridges in the Black River valley. The Port Huron moraine from Vassar to Cass City makes the valley of Cass river a long, pointed bay at the Arkona level, shallow and narrow at its head. Yet the Arkona beaches extend nearly to Cass City as gravel ridges almost as strong as they are farther west where they would be much more exposed. Towards Cass City these ridges become buried under sandy delta deposits near the mouth of the Ubly outlet channel. The situation is somewhat like that in Black River valley. With the Port Huron moraine where it is now these beaches could not have attained such strength as they show near Cass City. They were made before the moraine was built, and this moraine is the same one that stands in front of the Arkona beaches in the Black River valley.

(4) From their strength near Applegate and Cass City it seems certain that the Arkona ridges once extended northward around the thumb, crossing its crest a little south of Bad Axe. Between Cass City and Applegate, therefore, the Arkona ridges appear to have been overridden and destroyed by the ice when it re-advanced to the place of the Port Huron moraine. It is plain that the same re-advance that raised the waters on the east side of the thumb to the Belmore level would have no effect on the level of the water on the west or Saginaw side, because the outlet for the lake in the Saginaw valley was westward through the Grand River channel and the re-advance of the ice did not touch this channel or even come near to it.

In southeastern Michigan the Arkona beaches may therefore be divided with respect to their history into four provinces or areas. First, in the Saginaw valley they have not been modified in any way, either by overriding or submergence; second, on the thumb between Cass City and Applegate they have been overridden and destroyed; third, in the Black River valley they were submerged, but were, at the same time, so protected as to be preserved without suffering discoverable modification, and fourth, in the interval from Spring Hill southwest to the Ohio line they were submerged and greatly modified, their relief being much reduced—in some parts destroyed—and their composition changed by the infiltration of clay.

Evidences showing slight movements of re-advance on the part of the ice front were found in a number of places some years ago. But, with perhaps one exception, they show nothing definite as to the amount of re-advance. The relations on the thumb seem to show very clearly a re-advance of at least fifteen to twenty miles.

In that case, the re-entrant angle between the Huron and Saginaw ice lobes during the time of Lake Arkona was somewhere near Port Austin on the end of the thumb. This would leave a strait across the outer part of the thumb at the Arkona level connecting the waters on the two sides. In its re-advance the re-entrant angle of the ice pushed up the slope of the thumb to Ubly which is about two hundred feet higher than Port Austin. In the last part of its re-advance the ice carried the water level on the east side of the thumb up with it from the lowest Arkona beach to the Belmore beach, but did not effect the level of the waters in the Saginaw valley. Thus, Lake Whittlesey was an incident of a glacial re-advance following a movement of retreat during which Lake Arkona had its entire period of existence and made all of the Arkona beaches. Besides showing that there was a re-advance of fifteen to twenty miles, the Arkona beaches show that the time during which the ice front rested after its retreat and before its re-advance to the Port Huron moraine was fully as long as the time during which it rested on that moraine. While the ice front was resting near Port Austin before its re-advance it must have been building a moraine comparable to the Port Huron moraine. But this was probably overridden and destroyed during the re-advance. This overridden moraine was being built while the Arkona beaches were being made, and the time which they required for their making was time enough for the building of that moraine, just as the time required for the making of the Belmore beach was enough for the making of the Port Huron moraine.*

There are many evidences of re-advance of the ice front in other intervals of the general glacial retreat. If, as seems to be the case, every so-called "recessional" moraine marks the climax of a re-advance and if there was in each case so long a pause before the re-advance it seems plain that the rate of the general glacial retreat was slower and the time it occupied longer than some authors have supposed.

Fort Wayne, Ind.

*All these phases of the glacial retreat have been discussed in a previous paper. "Moraines of Recession and their significance in glacial theory," Journal of Geology, Vol. V, No. 5, 1897.

DRUMLIN AREAS IN NORTHERN MICHIGAN.

ISRAEL C. RUSSELL.

There are at least two regions in the Northern Peninsula of Michigan, in which drumlins form the most conspicuous features of the topography. One of these areas includes Les Cheneaux Islands and a part of the adjacent mainland, on the north shore of Lake Huron; and the other area is situated principally in Menominee County, to the west of Green Bay.

Les Cheneaux Islands area embraces about 70 square miles, the numerous drumlins within it are of the elongate, ridge like type, are in general about 40 feet high, and trend N. W. and S. E. The direction of ice movement to which the drumlins are due, as recorded by striæ, etc., on rock surfaces, was from the N. W. towards the S. E. Many of the drumlins are partially submerged in the water of Lake Huron and form Les Cheneaux Islands and the capes on the border of the adjacent mainland; the conspicuous parallelism of the longer axes of the islands and of the neighboring capes, is due to this cause. The drumlins are for the most part below the horizon of the Nipissing beach, and have been washed by lake waters so as to remove the greater part of the fine material formerly present on their surfaces; and concentrate the stones and boulders.

The Menominee area occupies at least 150 square miles, and contains many hundred and probably several thousand drumlins. The drumlins are mostly of the ridge like type, are usually about 40 feet high, and their longer axes trend N. E. and S. W. The till of which they are composed is reddish, sandy, without laminaton, and contains many flat slabs of limestone which are without orderly arrangement. Boulders of native copper and of specular iron ore found in the till, indicate that it was deposited by a glacier moving from the N. W. toward the S. E. Striae, etc., on rock surfaces in the midst of the drumlins, record an ice movement from the N. E. toward the S. W. The longer axes of the drumlins are not strictly parallel, but vary in trend from N. 32° E. to N. 55° E. The rocks on which the drumlins rest is Trenton limestone, and has a conspicuously even surface; no knobs or crags are present, such as might serve as nuclei for till accumulation. The larger drumlins rise to a uniform height and if the valleys and channels between them were filled a nearly horzontal plain would be produced. The depressions separating the drumlins are in many instances, smooth-surfaced, concave troughs; and in one example there is a well defined trench of this character, about 12 feet deep and from 20 to 30 feet wide, about the N. E. end of a small drumlin and extending along its sides. The surfaces of the drumlins to a depth of some 12 to 18 inches, are composed of exceedingly fine, dust like loamy sand, which contains loose stones and boulders.

The drumlins are for the most part smooth-surfaced, half cigar-shaped hills of the normal type, but in a few instances instructive irregularities are present. Among these are: A flattening of a portion of the normally elliptical ground-plan, as if a marginal portion of a well-shaped drumlin had been removed by erosion, leaving an abnormally steep slope; deep transverse trenches at right angles to their longer axes; straight or curved trenches extending from their summits down their sides; irregular pits in their normally smooth surfaces; and in one instance a terrace-like shelf with a convex longitudinal profile, parallel with the crest line of the drumlin on the side of which it occurs.

In the valleys between the drumlins there ae several eskers which as a rule are in a general way parallel with their longer axes, but in a few instances cross their trend nearly at right angles. In one example an esker extends each way from a transverse trench in a drumlin; and in a few instances eskers occur on the tops of drumlins.

From the evidence just summarized, the conclusion is drawn that the drumlins of the Menominee area were produced by ice erosion from a previously deposited till sheet. This explanation is essentially in harmony with the theory of the origin of drumlins advanced several years since by Professor Skaler.

Attention will also be invited to the importance of ice erosion in shaping the topography of glacial deposits in other regions.

Ann Arbor, Mich.

CHANGE OF LEVEL AT THE WEST END OF LAKE ERIE.

E. L. MOSELEY.

Abstract.

When the retreat of the glacier northward opened an outlet to the east for Lake Warren, the water was so lowered that it occupied only the eastern portion of the Erie basin. Subsequent tilting of the land depressed the western portion of the basin relative to the outlet at Niagara so that Lake Erie has gradually attained its present dimensions. The tilting still continues and the lake is enlarging. The effect of the deepening and spreading of the water is shown in many ways.

The streams entering the lake have slack water extending quite a distance from their mouths, in case of the larger ones several miles. Near the mouth of each is a marsh. Streams have been examined in the vicinity of Cleveland, Sandusky, Toledo and on the Canadian side. When the lake was at a lower level the streams cut their valleys deeper than would be possible under present conditions. A number of these valleys extend more than twenty-five feet below the present lake level.

Under Sandusky Bay the stream valleys extend miles beyond the present mouths of the streams. They have been filled with soft mud which can be distinguished from the glacial clay by examining the bottom with an auger. Submerged valleys of all the streams within five miles of Sandusky have been traced in this way. The

valley of Pipe Creek has been traced not only under the bay but under the sand bar that separates the bay from Lake Erie and into the lake. The mud accumulated in the submerged valley of Sandusky River south of Johnson's Island is now thirty feet deep.

Submerged Indian graves have been discovered on Squaw Island at the present mouth of the Sandusky River. Submerged forests have been found at Put-in-Bay and in different parts of Sandusky Bay, in one place extending out half a mile from the present shore. Submerged stalactites or stalagmites have been found in four caves of Put-in-Bay; in Daussa's cave, five feet below mean lake level.

About Sandusky Bay several square miles of what in 1820 was forest or prairie land is now marsh. The entire enlargement of the bay and connected marshes since 1820, due partly to subsidence, partly to erosion, is something like twelve square miles. The shores of Lake Erie have receded. This is true of Erie, Cuyahoga and Lake counties, Ohio, and of the vicinity of Port Stanley, Ontario, in fact wherever investigation has been made except short portions of the shore in a few places. At various places about the lake roads have been changed because of the encroachment of the water and orchards and houses have been undermined. The average recession of the shore west of the Pennsylvania line is probably not less than twenty-five rods in the past century on both the south and north sides of the lake but the data at hand are not sufficient for a good estimate.

The flora of the islands of the Put-in-Bay group and Kelley's Island indicates that they formed part of the mainland in post-glacial times. If all of the uncultivated plants growing upon them had in one way or another reached them by crossing the intervening water, we would expert to find on some of the islands plants well distributed which on others were wanting because the seeds had never reached them and we would expect to And that some of the plants well distributed in similar soil on the mainland were altogether wanting on the islands. But what we find is the reverse of this. (See Sandusky Flora, Ohio Academy of Science, Special Papers No. 1.)

In 1838 trees centuries old were killed by the water standing over their roots and many others in 1858. This occurred about Sandusky Bay, on Kelley's Island, Put-in-Bay, Middle Bass and along the shore between Port Clinton and Toledo. The early settlers could recall many observations that showed the water in the first part of the nineteenth century was not so deep as it became later.

The terminal portion of the Cedar Point peninsula at the entrance to Sandusky Bay is formed of parallel sand and gravel ridges that have been thrown up by great northeast gales occurring at times when the lake was above its normal level. The ridge nearest the bay is the oldest and that nearest the lake the youngest. By studying the vegetation it has been possible to determine the approximate age of each of the principal ridges. Beneath the wind-blown sand the ridges contain stratified sand or gravel or shells of molluscs showing the height to which the materials were thrown by the waves. Each of the principal ridges was dug into in many places in order to ascertain the maximum height of the aqueous deposits in it. These deposits are at a higher level in the recent ridges than in the earlier ones. Dividing the number of feet showing the difference in level between any two of them by the difference in time of their formation in centuries gives the number of feet per century that the lake has risen. It is about 2.14. (For a detailed description of these ridges see "Formation of Sandusky Bay and Cedar Point" published by the Ohio Academy of Science.)

Sandusky, Ohio.

A STUDY OF PLANTS IN RAVINES NEAR ADRIAN.

FRANCES L. STEARNS.

An attempt has been made to correlate the development of vegetation of the river valley with the physiographic changes which have marked the history of its establishment. These, briefly outlined, are the gully, the ravine, first with steep sides and later with a gentler slope, the bluff, and flood plain with meandering streams—this study does not include the flood plain.

The area worked on is a small part of the bank of the Raisin River at Adrian and the ravines of one of its tributaries. The Raisin is a small, sluggish stream meandering in a valley one-half to one mile wide with outer banks 25 to 100 feet high and at this point drains a part of the Defiance terminal moraine. The moraine forms knolls and depressions and the small streams are continually cutting back gullies and ravines. The soils are various, gravelly till, clay, sand and muck, seeming to be scattered without any system. Part of the drift is land-laid and in other places the gravel and sand is sorted by water and distinctly stratified. The development of the drainage is closely allied with the glacial history of the region and the mature river valley in its present condition may have passed through stages not now illustrated by any portion of the system, but various phases appear which can be taken as stages in the developmental history.

The initial stages of ravine formation are seen in the gullies. Where the original forest covering has been cut and the land is under cultivation the gully eats back rapidly, the washouts being most destructive in sandy and gravelly fields, no water remaining in the gully.

The first gully studied was in a cultivated field and was in a broad depression. It was about 50 feet long and 6 feet deep and cut through sand underlaid by clay. The shifting of the newly exposed soil produces nearly desert conditions. The plants which do develop are annuals or plants which have fallen down the side carried by part of the bank or those which spread by rootstalks.

The weeds of the cultivated field early gain a foothold on more stable sides. These are such plants as ragweed. Ambrosia artemisiæfolia, Lactuca scariola, Plantago

major which are characterized by rapid growth and seed dispersal and protection from destruction by animals. Other weeds from neglected meadows, such as Aster and Thistle, are introduced by the seeds carried by wind. The most striking example of plants spreading by root stalks is Rumex acetosella. This is best seen in the second gully studied. This was in the same field and was about 90 feet long, 20 feet deep and cut in sand. Here Rumex sends rootstalks often five feet long down the side of the bank, acting as a soil binder. The same work is done less perfectly by grasses and sedges. This gully is very barren of vegetation, fewer weeds having developed than in the first. In the first of these gullies a small part of the side was covered by a characteristic ravine growth. Where the water seeped out of the soil, keeping the surface moist, mosses, algae and liverworts appear. Oscillatoria, Botrychium and Conocephalus occur together.

The third gully is in open pastured oak-hickory woods. The soil is sand with a clay layer below. In this gully or young ravine there is great conservation of moisture and we find a smaller development of weeds; shrubs, blackberry and raspberry, gain a foothold; there is a greater development of hydrophytic mosses and algae; the more hydrophytic plants characteristic of river margin invade the ravine running back from the river, examples are Prunella vulgaris and Impatiens biflora; herbs of oak-hickory forest, as Campanula rotundifolia, occasionally occur.

Gullies cut in the deeply shaded forest where there has been little change of drainage progress more slowly, since they are filled by accumulation of vegetable matter which enriches soil, holds moisture and prevents destruction by rain wash. The desert condition rarely appears in these localities or is of short duration. The gullies on the river bank studied are of this type, but are not in natural condition, being held by brush, etc.

A desert condition may also occur when the meandering stream cuts into the old outer bank. Here banks 20-50 feet of clay or sand rise almost vertically from the river and are devoid of vegetation except that which falls from the top. In this locality the destruction seems more rapid in clay than in sand, just the opposite being true for lateral extension of gullies.

Ravine I is three hundred feet long and thirty or more feet deep at its oldest part widening to twenty-five feet. It is cut partly in clay and partly in sand. There is an oak-hickory forest on the west and cultivated field on the east. Near the head the banks are washed out, forming side gullies, farther down we have true ravine, well developed, passing into a broad ravine at the outlet. The gullies are sand and are desert or are held by blackberry thickets in whose shade mesophytic herbs develop. There are also climbers, Rhus and Ampelopsis.

As some stability of bank is attained two groups of plants appear, a group of shrubs abutting on the forest and represented by Carpinus Caroliniana and Hamamelis Virginiana and a rich flora of mesophytic herbs on shady banks; this includes Adiantum pedatum, Trillium grandeflorum, Thalictrum dioicum, Mitella diphylla. The shrub zone rarely reaches the water's edge, but the stream is bordered by herbs and more hydrophytic plants, as Conocephalus, which also grow on the wet clay bank. These plants are adapted to shade, they bloom early and have thin leaves.

Scattered groups of Acer rubrum and Populus tremuloides occur on the bank.

In the shade of these shrubs and trees seedlings of the oak-hickory forest are developing and young Ulmus Americana, Tilia Americana, and Praxinus Americana are found.

In Ravine II practically the same relation of plants is found, but heavy blue clay is in all of the bottom and there is a much larger area covered by hydrophytic plants and stream margin and bog plants are found.

A broad ravine is found on the bank behind the cemetery where a small stream cuts through the river bank. Here we have deep shade and the size of the trees shows great age. There is an absence of pioneer plants even on the cut sides. The gully is filled by leaves. The characteristic thing is the mesophytic trees, Tilla Americana, Ulmus Americana, Acer saccharinum and with them Carpinus and Hamamelis. There are also shrubs which belong to the oak-hickory forest, Cornus floridus, Prunus Virginiana and the oak and hickory have invaded from the bank.

The arrangement of plants on an established bank is better shown in the diagram, 50 feet high, 120 feet long. This bank is 66 feet above level of the river.

The highest parts are covered by the oak-hickory forests spreading over bank. It soon meets the zone of ravine plants, elm, basswood, Hamamelis and the herbs, Thalictrum dioicum, fern, etc. There is a struggle to hold the bank and the oak-hickory is gaining ground. Below this the slope is wet by hillside springs and forms a bog which has a characteristic flora. The soil is black humus with much organic matter and with much lime a few feet below the surface. Still lower, quicksand is found. The plants which grow here are Tilia Americana Fraximus Americana, Cratægus, Ribes, Xanthoxylum Americana, but most abundant Spathyema, sedges, mosses, Cardamine bulbosa, Eupatroium, purpureum, Lobelia sylphitica, Galium asprellum, etc.

Its position suggests that this bog may not have been a part of ravine development, but may have been swamp or lake bottom when the river stood at different level. Mastodon bones found in similar place a quarter of a mile further point toward ancient origin.

The succession of groups of plants is shown by chart.

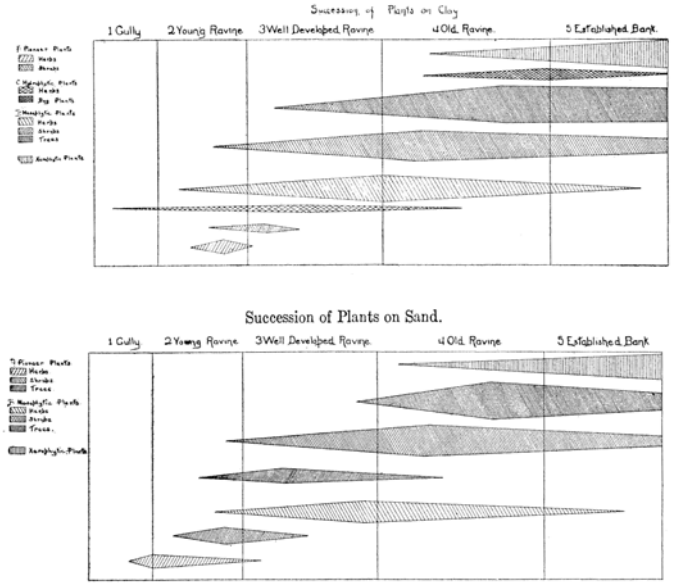


FIG. 1.—Charts showing the succession of plants in the development of ravines in clay and sandy soil

LISTS OF PLANTS CHARACTERISTIC OF RAVINES.

Characteristic Pioneer Herbs
- Poa
- Rumex Acetosella
- Chaetolochia glauca
- Euphorbia maculata
- Lactuca Scariola
- Plantago major
- Rumex crispus
- Leptiloa Canadenses
- Ambrosia artemisiaefolia
- Lepidium Virginicum

Characteristic Pioneer Shrubs
- Rubus nigrobaccus
- Rubus occidentalis
- Rhus radicans
- Sambucus Canadenses
- Ribes cynosbati

Characteristic Pioneer Forest
- Acer Rubrum
- Populus tremuloides
- Populus grandidentata

Characteristic Mesophytic Trees
- Ulmus Americana
- Tilia Americana
- Acer Saccharinum
- Fraxinus Americana
- Ulmus fulva

Characteristic Mesophytic Shrubs
- Carpinus Cariolinana
- Hamamelis Virginiana
- Crataegus sp
- Cornus alternifolia (?)
- Prunus Virginiana (?)
- Parthenocissus quinquefolia
- Rhus radicans
- Amelanchier Canadensis

Characteristic Mesophytic Herbs
- Mnium
- Funaria
- Aulicomnia
- Bartramia
- Conocephalus
- Onoclea sensiblis
- Adiantum pedatum
- Polystichum acrostichoides
- Thalictrum dioicum
- Geranium maculatum
- Hepatica Hepatica
- Galium boreale
- Vagnera stellata
- Vagnera racemosa
- Trilium grandiflorum
- Salomonia biflorum
- Mitella diphylla
- Uvularia perfoliata
- Deringa Canadenses
- Solidago sp
- Aster sp

Characteristic Trees of the Oak-Hickory Forest
- Quercus alba
- Quercus rubra
- Quercus coccinea
- Hickoria glabra
- Hickoria alba

Characteristic Shrubs of the Oak-Hickory Forest
- Cornus florida
- Prunus Virginiana
- Ostrya Virginica
- Corylus Americana
- Crataegus sp
- Malus coronaria
- Gaylussacia resinosa
- Sassafras Sassafras
- Smilax rotundifolia

Characteristic Herbs of the Oak -Hickory Forest
- Antennaria plantagnifolia
- Falcata comosa
- Campanula rotundifolia
- Vicia Caroliniana
- Solidago sp.
- Hieracium scabrum
- Aster sp.
- Equisetum hymale
- Poa pratense
- Hepatica Hepatica
- Deringa Candensis
- Euphorbia corollata
- Monarda fistulosa

Characteristic Plants of Spring Bank
- Trees
  - Tilia Americana
  - Fraxinus Americana
  - Ulmus fulva
  - Carpinus Caroliniana
- Shrubs
  - Sambucus Canadensis
  - Xanthoxylum Americana
- Herbs
  - Conocephalus
  - Mesophytic mosses
  - Spathyema foetida

Characteristic Plants of Spring Bank
- Herbs
  - Geranium maculatum
  - Cardamine bulbosa
  - Menispermum Canadensis
  - Eupatorium purpureum
  - Teucrium Canadense
  - Cicuta maculata
  - Lobelia syphilitica
  - Galium Aparine
  - Galium asprellum
  - Senecio aurens
  - Sedges

Characteristic Plants of the Stream Margin
- Epilobium coloratum
- Impatiens biflora
- Eupatorium perfoliatum
- Prunella vulgaris
- Ranunculus sp

Hydrophytic Plants
- Oscillatoria
- Botrydium
- Conocephalus
- Mosses

Note. The nomenclature of Britton's Manual has been used.

The distribution of the plant groups is conditional on several factors: The first is the drainage. In general the height above water level divides the vegetation into upland and lowland floras. The first of these is mainly the one we have to deal with.

Usually the banks are dryer than the lowlands, but this is locally varied by the slope of the bank, steep banks not retaining water as well as slopes; again the moisture content varies with the soil, clays and water retaining soils may sustain mesophytic or hydrophytic groups of plants even on steep slopes; the collection of humus increases the water retaining power of soil, old banks even of steep slope supporting mesophytic plants.

Secondly, the physical nature of the soil also affects the succession in another way. The penetration of clays and hard soils by root stalks and seedlings is more difficult than of loose soils and these plants therefore appear later in clay. On the other hand the wet clay invites surface plants, as mosses, etc., and they readily develop. The pioneer herbs and shrubs which have rapid growth, are limited in clay.

Third, the atmospheric conditions affect the moisture content of the soil. The air is dryer and has a greater range of humidity on the banks than in the lowlands.

The temperature of both air and soil varies more on the high bank than in the lowland, while the soil of the bog below the surface has a lower and more constant temperature than is found elsewhere.

The light intensity probably excludes some plants from young ravines which develop when shade is afforded.

The most conspicuous factor affecting the succession of ravine plants is erosion. The cutting away of the soil desrtoys the old flora or carries it into the ravine and the cycle may be interrupted at any point and the succession started anew.

Adrian, Michigan, March 30, 1905.

PLANT DISTRIBUTION IN A SMALL BOG.[1]

EDITH E. PETTEE.

The bog studied is about four miles southeast of Ann Arbor, Mich., in one of the many morainal depressions of that region. It is about thirty-nine rods long and seventeen rods wide, and is surrounded by steep banks which are forty feet high at the west end, sloping down on both sides to within three feet of the swamp level at the east end. On the north side there is a depression in the hillside, and a consequent widening of the swamp at that point of at least fifty feet. The area drained is very narrow on all sides and there is no definite channel draining into the swamp.

The bog is undrained except for excess of water, which is taken oft in times of flood by a shallow ditch at the east end. The surface of the swamp is nearly level and there is no evidence of its ever having stood at a higher level than at present.

The underlying soil is heavy blue clay. Borings show a slope of the bottom on all sides toward the center, as indicated in the diagram. The dotted lines show estimated depths which have yet to be determined.

The hills around the bog seem to have been covered by an oak-hickory forest which has all been destroyed except on the high west hill and its east facing slope. On the top of the hill are found:—

Quercus rubra, Quercus velutina, Quercus alba, Hicoria ovata, Hicoria alba, Acer saccharimim.[2]

There is no underbrush and few herbs except grass.

On the east facing slope we find

Quercus rubra Quercus velutina, Quercus alba, Hicoria ovata, Hicoria minima, Hicoria alba, Juglans nigra, Prunus sp. (cherry), Juniperus communis, Primus Americana, Rubus occidentalis.

Rubus nigrobaccus, Hamamelis Virginiana, Crategus 2sp., Corylus Americana, Cornus stolonifera, Rosa Carolina ,Galium sp., Vagnera racemosa, Celastrous scandens, Vicia sp., Dioscorea villosa, Parthenocissus quinquefolia, Thalictrum dioicum, Asclepias Syriaca, Linaria Linaria, Falcata comosa, Podophyllum peltatum, Pyrola elliptica, Impatieus biflora Geranium maculatum, Cnicus Lanceolatus,

The south bank is occupied by a second growth of young trees and shrubs. We find here:

Quercus rubra, Quercus velutina, Quercus alba, Quercus coccinea, Hicoria alba, Hicoria ovata, Rubus occidentalis, Rubus nigrobaccus, Populus grandidentata, Populus tremuloides, Carpinus Caroliniana, Hamamelis Virginiana, Corylus Americana, Aronia arbutifolia, Acer saccharmum, Crategus (Several species), Vaccinium vacillans, Rhus glabra, Vitis sp., Smilax sp., Hepatica Hepatica, Antennaria plantaginfolia, Mitchella repens, Penstemon sp., Rudbeckia hirta, Achillea Millefolium, Viola pubescens, Mitella diphylla, Vicia sp., Carex sp., Thalictrum dioicum, Polytrichum commune, Prunella vulgaris, Aster cordifolius, Prunus sp.

On the north side there is a cultivateded field with patches of this young-tree-and-shrub zone fringing the swamp as shown by the presence of

Hamamelis Virginiana, Corylus Americana, Prunus, etc.

The bog proper is divided into three very distinct regions:—

1. A Marginal zone. 2. An intermediate zone. 3. A central area.

The marginal zone averages about twenty-five feet wide and has a distinctly different vegetation from the rest of the swamp. Ten of the thirteen plants given by Transeau[3] as typical of drained swamps are found here. The ones not found are

Scirpus lacustris, Polygonum emersum and Fraxinus Americana.

[1]This work was done in the summer of 1904 under the direction and with the assistance of Dr. G. P. Burns.

[2]The names used are those of Britton's Manual of the Northern States and Canada, 1901.

[3]Transeau E. N. On the Geographic Distribution and Ecological Relations of the Bog Plant Societies of Northern North America.—Botanical Gazette, December, 1903.

The following plants are found here: (The first ten are the ones in Transeau's list),

*Carex riparia, *Juncus effusus, *Polygonum sagittatum, *Typha latifolia,* Cornus stolonifera, *Cornus candid issima, *Salix discolor, *Ulmus Americana, *Cephalanthus occidentalis, *Acer rubrum Scirpus atrovirens, Impatiens biflora, Polygonum 2 sp., Erechtites hieracifolia, Spathyema foetida, Panicularia nervata, Osmunda regalis, Osmunda cinnamomea, Onoclea sensibilis, Dryopteris 3 sp., Spirea salicifolia, Rosa Carolina, Naumbergia thyrsiflora, Rumex verticillatus, Koellia Virginiana, Monarda fistulosa, Roripa Armoracia, Salix lucida, Salix petiolaris, Salix sericea, Salix 2 sp., Ilex verticiliata, Oxalis stricta, Viburnum Lentago, Viburnum acerifolium, Sambucus Canadensis, Prunus Virginiana, Prunus sp., Ribes floridum.

The characteristic plants of this zone are the sedges and shrubs which are intermingled except along the west end where the shrubs are lacking. Next to the open field there is a much greater number of genera and species than anywhere else. Impatiens is abundant at the shaded southwest corner and the polygonums at the more sunny north west corner. The intermediate zone is the main area of the bog and here are found:—

Rhus Vernix, Vaccinium corymbosum, Acer saccharinum, Acer rubrum, Larix laricina, Aronia arbutifolia, Ilicioides mucronata, Viburnum Lentago, Sambucus Canadensis, Rubus strigosus, Rubus occidentalis, Populus grandidentata, Populus tremuloides, Osmunda cinnamomea, Dryopteris 3 sp., Unifolium canadense, Coptis trifolia, Sphagnum, Mosses, Typha latifolia, Solarium Dulcamara, Monotropa uniflora, Naumbergia thyrsiflora

Both red and black raspberries are found in open spaces where trees have been cut out; but the red ones are frequent while the black ones are rare. On the hillside the reverse is true. In the dense shade of the larger maples and thick patches of Vaccinium corymbosum the undergrowth of herbs is very scanty.

The plants in the central region are

Chamaedaphne calyculata, Sarracenia purpurea, Cypripedium acaule, Oxycoccus oxycoccus, Vaccinium corymbosum, Sphagnum, Larix laricina, Carex trisperma, Rhus Vernix, Bidens sp., Mosses.

This seems to be the only place where the Sphagnum is really thriving. Carex trisperma is very abundant here and is not found to any extent in any other place in the swamp. Examination of the rings of wood on the stumps of half a dozen tamaracks showed an unusually slow growth between the years 1880 and 1890.

The marginal zone and the central region have no plants in common and are separated from each other by a region which has some of the plants from each and some from the surrounding hillside together with others found in none of these places.

These marked zones of vegetation and examination of the soil conditions show this bog to be not at all a homogeneous habitat, but decidedly heterogeneous.

Cattle are at times allowed free access to the swamp and have frequented the margin at the west end more than anywhere else. They may have had much to do with keeping the shrubs from getting a foothold here. Possibly they have had some influence in aerating the margin—thus making it more like a drained swamp.

MacMillan[1] describes the formation of plant atolls in lakes in Minnesota: Shaw[2] found a marginal ditch around bogs near Woods Hole due to falling leaves smothering out vegetation in that region; and Atkinson[3] suggests the same condition in New York may be due to shading of the margin of the bog. It is not clear how this marginal region could have originated in any of these ways.

Davis[4] finds this marginal zone common in bogs in Michigan and believes it is caused by fluctuating water supply in this shallow part of the bog due to variation in annual rainfall and temperature. Then we would expect to find the marginal zone widest in the shallowest part of the basin, but much to our surprise we found the widest part of the zone deeper and wetter than any other part.

The west end of the swamp is deeper and has more water in the soil than the east end. Here we find poison sumac and huckleberry thriving best while at the shallow east end maples

predominate and poplars are coming in, and the huckleberry bushes are dying out in the dry coarse leaf mold in the shade of the maples. The tamarack is the only plant of the central region which is still thriving in the rest of the swamp.

Livingston's[5] determination of the osmotic pressure of bog waters shows that we can no longer consider the presence of humous acid a physical cause for the xerophytic character of the plants of the central region. A few preliminary thermometer readings seemed to indicate that the soil is colder here than at the same depth in other parts of the bog.

[1]MacMillan, Conway. On the Occurrence of Sphagnum Atolls in Central Minnesota.—Minnesota Botanical Studies, 1. No. 9, 1894.

[2]Shaw, C. H. The Development of Vegetation in the Morainal Depressions of the Vicinity of Woods Hole.—Botanical Gazette, June, 1902.

[3]Atkinson, G. F. Lessons in Botany.

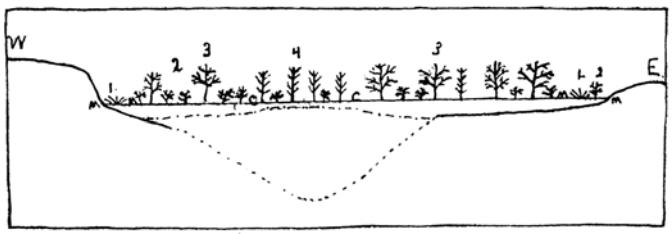
[4]Davis, C. A. An article yet unpublished.

[5]Livingston, B. E. Physical Properties of Bog Waters.—Botanical Gazette, May, 1904.

The distribution of the vegetation seems to have a definite relation to the height at which the ground water stands. The broken line in the diagram shows the approximate condition of affairs during the summer of 1904. It comes almost to the surface in the center and is nearer the surface at the west end and north side than at the shallow east end. It seems to be held at the surface by the sphagnum which is very little disintegrated in the center, while the soil in other parts of the swamp is physically in a very different condition. This varying physical condition would greatly affect its moisture holding capacity.

We have here a dying tamarack swamp bounded by a marginal zone which seems to have been influenced by other factors than the rest of the swamp. The distribution of the swamp plants seems to have a definite relation to temperature, the physical character of the soil, depth of the bog, and level of the ground water. The investigation of these subjects is being continued and a fuller report will appear later.

University of Michigan.



Profile of bog from west to east.
Scale: Horizontal 80.4 cm=1mm, vertical 61 cm=1mm.
1. Sedges.
2. Shrubs.
3. Maples.
4. Larix laricina.
C—C. Center.
M—M. Margin.

RAVINES IN THE VICINITY OF ANN ARBOR.

BY ALFRED DACHNOWSKI.

(An Abstract.)

Preliminary to more extended work in the field in experimental physiology, the attempt is made to give a brief ecological summary of the various ravines in this vicinity. For convenience four phases are emphasized in ravine processes, corresponding to relatively dominant ecological factors. They are:

(1) A locally typical ravine.
(2) A ravine influenced by man.
(3) A ravine of arrested development due to captured territory.
(4) A rejuvenated ravine.

The results obtained show that in each ravine the vegetation, though more or less similar, is decidedly influenced by conditions of soil, light, water-content, temperature, etc., as determined by geology, topography, man, the plants themselves, or the combination of these with other agencies. Concrete cases make it obvious that no ecological factor can be cited as exclusively determining the character of the local flora. Many changes in kind and arrangement of vegetation are independent of dominant ecological agencies. They are results which arise from the united action of these factors and, in turn reacting upon the conditions present, thus lead to changes in habitat and consequent distribution of plants not to be attributed either to topography alone, water-table, or character of soil. The main stress must be laid on process, i. e., the varying causes actively at work which bring about the modifications in ravine life, if we are to avoid inconsistencies in definite classification of plant societies. But equally important is the fact that such data must be reinterpreted by the physiological condition of the plants growing in the environment.

University of Michigan, Botanical Laboratory.

A STUDY OF SOILS BY YOUNG STUDENTS.

J. A. JEFFERY.

In preparing an outline for the study of soils in rural schools, it is borne in mind that the pupil, the condition and the teacher will each have a bearing upon how closely any outline shall be followed.

The following short outline is one which I would suggest, subject, as indicated above, to modification. The time required for the work will depend on the time at the teacher's disposal. In the ordinary country school the work would have to be done largely during the spring and fall terms.

APPARATUS REQUIRED.

Little can be done without some apparatus.

It would be desirable, of course, to have a laboratory with a lot of good apparatus, but even with simple and crude tools, one is often enabled to obtain excellent results.

A torsion balance weighing to 1-10 gram, glass tubes, glass funnels, glass jars, filter paper, graduates and evaporating dishes are desirable.

This article is written for a laboratory supplied with apparatus as follows:

One kitchen scale with dial, weighing from one ounce to 24 pounds, price 90 cents.

One dozen, gallon jars—of the deep sort.

One dozen common glass tumblers.

One and one half dozen quart tin fruit cans (tomato cans) with open end melted off by placing can, open end down, on a hot kitchen stove for a few minutes.

One dozen tops of baking powder cans.

One common eight ounce graduate such as can be bought in most grocery stores.

A few dozen screw cap bottles, seven-eights inch by five and one-half inches, or thereabouts.

One small bottle of ammonia.

One small alcohol lamp.

A Soil Collection.

(a) Have each member of the class bring a quart sample of soil. This sample should be obtained by digging a hole with perpendicular walls to the depth of the plowed soil, or, in virgin soil, to the depth of the soil proper as indicated by the darker color due to the presence of the larger quantities of organic matter. In muck soils take sample to depth of six inches. Mix thoroughly before taking the quart sample.

(b) These soils should be air dried, thoroughly mixed, and smaller samples taken from these to preserve. A screw cap homeo, 7 inch by 51/2 inches, makes a very convenient receptacle in which to preserve samples.

(c) Have the pupils place these samples in groups so far as they may be able to on the basis of appearance, feel, etc. If they have any difficulty in this let the teacher suggest and later, if necessary, complete the classification.

There are likely to be in this lot of soils, sandy soils, loams, clays, and muck soils with intervening modifications. In some cases sub classifications on the basis of color, might be required. Or some special form of soil, such as an alluvial, might be brought in.

(d) If these vials of soil could now be mounted in some permanent form, for reference from time to time, say upon heavy cardboard with light copper wire, it would be helpful.

(e) Have samples of the sub-soils brought in the same manner for a depth of six inches below the depth of the first sample. Dry, bottle, and place each with its soil.

(f) It would be well to carefully save the remaining soils after bottling the samples.

Composition of Soils.

(a) Have each pupil study a sample of the soil he has brought, (and later, samples of soil brought by the others) and let him as far as possible determine what materials compose it.

(b) In a qualitative way the relative amounts of organic matter fine material, and sand of each soil may be determined:—

1. The organic matter, by burning a quantity of each soil. The soil may be placed in a can cover and the cover and contents placed over the alcohol flame or on a bed of hot coals or upon a hot stove top.

2. The coarse, sandy material may be determined by placing a quantity (about one ounce) of soil in an ordinary glass tumbler. Fill the tumbler half full of water, add a few drops of ammonia and allow to stand for twenty-four hours stirring from time to time. After twenty-four hours fill the tumbler nearly full of water, stir well and after standing one minute, pour off the water with everything left in suspension, repeating till nothing is left in suspension at the end of one minute.

3. The finer clayey material would be estimated by difference.

By the use of the 90 cent kitchen scale this work could be done quantitatively with aproximate accuracy, though larger quantities of material should be used. This would require, also, that the material be air dried before and after separation before weighing.

Soil History.

It would be possible at this point to give some attention to the manner in which some of the soils have been formed. The alluvial soils and the muck soils are especially suited to give the pupil an opportunity, under the direction of the teacher, to develop something of their history for himself. The teacher might give a few of the simpler facts concerning the formation of all the soils brought in by the pupils. Visits might be profitably made, at times, to soil deposits.

Physical Characteristics.

Simple experiments may be performed to illustrate some of the more important qualities of soils such as:

(a) Water holding power. If funnels of glass are not at hand a quart tin tomato can as described above, will do. With a nail or other tool, punch a small hole in the bottom close to the side.

1. Weigh the can.

2. Weigh in one pound of air dry soil, first placing a moistened piece of old fine muslin over the hole punched in the bottom.

3. Now introduce more than sufficient water to saturate the soil.

4. Place the can with its contents in a tilted position with the hole down, and allow to drain until! water ceases to drip.

5. Weigh and determine the amount of water retained in the soil.

It is best to use two to several kinds, or types of soil at the same time. Cans are not expensive to obtain.

(b) The rate at which soils give up moisture.

1. Fill two one gallon jars even full with a soil containing about the amount of moisture it would require in the field to plow well. Pack the soil reasonably well. Number the jars.

2. Weigh jars and contents and record weights.

3. At the end of one week, weigh again, record weights, and estimate losses.

4. Add water sufficient to bring weight of jar back to original weight.

5. At the end of another week, weigh again and proceed as in (4).

It would be well to carry this work through a number of weeks using three or more lots of soil.

(c) Effects of standing water.

1. Place in bottom of a glass tumbler a piece of moistened paper large enough that when fitted well down against the bottom it will reach half way up the sides of the tumbler.

2. Introduce into the tumbler one ounce of air dry soil.

3. Cover with water and allow to stand twenty-four to forth-eight hours.

4. Without stirring, pour off excess of water and allow tumbler to stand in a warm place till the soil in the bottom becomes thoroughly dry.

Soils of different kinds should be so treated at the same time for convenience in comparison.

Compare effect of this treatment on different soils.

5. Have pupils observe whether field soils in the neighborhood are made hard by heavy rains or by water standing on the field, and how such a condition of field soil effects the crop.

Effect of Cultivation on Moisture Losses.

1. Fill full four one gallon jars of the deep sort, with any good soil in well moistened condition. Pack well. "Strike off" the surfaces with a straight edge. Number the jars, 1, 2, 3 and 4.

2. With a table fork, thoroughly stir the surface soil of jars 3 and 4 to a depth of an inch, and "strike off" with straight edge.

3. Weigh all four jars and record weights.

4. Place jars either in open room or out of doors, but not where rains may strike them.

5. At end of one week weigh again and record weights, estimate and compare losses from the jars cultivated with those not cultivated.

6. Add sufficient water to each jar to bring it back to its original weight and after a little time stir the surface of the jars 3 and 4 again.

7. Repeat (4) and (5).

Water Used by Plants.

1. Fill four one gallon jars to within one inch of the top with a well moistened soil.

2. Number jars 1, 2, 3, and 4 and weigh and record weights.

3. Plant eight good plump kernels of oats, or four good kernels of corn in each of the jars 3 and 4. Place all jars where rain will not reach them.

4. When plants are three inches high, thin the oats to six plants, or if corn, to three plants. Add sufficient water to bring each jar to its original weight.

5. In one week, weigh again, record weights, estimate losses, and with jar on the scale, add water sufficient to bring it up to its original weight. Note losses from jars with plants as compared with losses from jars without plants.

6. Repeat (5) for several weeks noting how, as the plants grow larger, larger quantities of water are used.

It will be necessary when the plants are well started, to add water oftener than once per week to the jars having plants in them.

7. Have pupils examine cultivated fields and observe, if possible, whether any difference in appearance exists between the crops in well cultivated fields and those of poorer cultivated fields, keeping in mind this experiment and the one above.

With a little effort, this scheme may be considerably enlarged. Experiments with field soils and crops are entirely feasible.

Agricultural College, Michigan.

THE BLACK RIVER SECTION NEAR BESSEMER.

W. C. GORDON.

During the months of July, August, September, and a part of October the Mich. Geol. Survey had a party of men making a section of the Keweenawan rocks as they are exposed between the city of Bessemer and Lake Superior. It is the attempt of this paper to give some idea of the work done by that party.

Bessemer is a city of about 4000 population, lying for the most part in S. 10 T. 47 N., R. 46 W. It is on the C. & N. W., and Wis. Cent. Ry's. and is entered by a spur line of the D. S. S. & A., the main line of which passes two miles to the north. It is an iron-mining town on the Gogebic Iron Range. Six miles to the west of it is the Wisconsin state line.

Immediately around the village the land is cleared and under cultivation, but the D. S. S. & A. Ry. marks the northern limit of cleared land, beyond which is the virgin forest.

Just north of, and passing so close as to almost touch the city limits, is an east and west ridge rising from 200 to 250 feet above the surrounding country. In places it develops into steep bald hills, and even bluffs. The ridge is broken through frequently by north and south gaps which vary in width from a few hundred yards up to a mile. These gaps immediately suggested to Dr. Lane the possibility of north and south faults, and later investigation proved the suggestion a true one. North of this ridge the country is flat and drift covered for about six miles; or, if we may express it so, there is a gap six miles wide extending east and west. Beyond this gap is again hill country, but not a continuous ridge. To the west is an isolated peak whose eastern side presents a cliff of felsite about 100 feet high, the hill itself rising nearly 250 feet. This hill is known as Chippewa Bluff. Eastward from this bluff, and about two miles away, is a hill of basic rock having about the same elevation. The rather broad top of this hill makes it have somewhat the appearance of a highland. Between these last two hills is a north and south gap. Directly north of Chippewa Bluff, and distant about three miles, is a conglomerate ridge whose longer axis extends east and west. This ridge is about two miles long. Beyond it, and not far distant, is Lake Superior.

Black River enters the area worked just north of the east and west ridge spoken of above. After flowing westward, practically along the foot of this ridge, for about three miles it turns northward and soon swings somewhat to the east. It flows to the east of Chippewa Bluff, taking to the low land that lies between it and the highlands that lie to the east. As it continues its northern course it is forced still further east around the conglomerate ridge, after which it takes a direct route to Lake Superior.

The river is from one hundred to one hundred and fifty feet wide, but is very shallow. During the low water of

August, even a small rowboat could not continue with uninterrupted passage. But during flood season it rises several feet. All along its course there are rapids. Those in the upper part, being caused by the collecting of glacial boulders in the stream bed, are small. Farther north, in S. 21 T. 48 N., R. 46 W., the river cuts down to the country rock and from that point the rapids increase in frequency and in size. The last three miles is a mere succession of rapids and falls and presents very picturesque scenery. In all, the river has about 600 ft. fall from the time it enters the area worked by the party to its mouth. That portion south is also said to be rapid, but the party was not on the upper part of the river at all. The river water is dark but I do not know whether this is the source of the name "Black River" or not.

Along the west bank of the river, sometimes close, and sometimes as much as a half mile distant, is a road from Bessemer to the lake. The road was originally cut through by the government, after which it was handed over to the township of Ironwood in which it lies. As there is no land under cultivation along the road, and nothing at all save a small fishing station at its lake end, there is practically no travel over it, except by pleasure-seekers. As a result the road is kept in poor condition.

The country so briefly described above is the one in which the survey party spent the season of 1905. They worked a strip four miles wide extending from Bessemer to the lake. The strip takes in the west four miles of R. 46 W. and extends across T's 49 and 48 N. and two miles into T. 47 N. Its southern extremity lies south of the east and west ridge spoken of as passing so near the Bessemer city limits, and extends north. It crosses the six miles of drift covered country, and covers Chippewa Bluff and the highlands to the east. It also takes in the conglomerate hill farther north. Flowing practically down the center of it is Black River.

The road along the west bank served as a convenient avenue for the party to reach different parts of the area they were working. A still greater boon was the advantage of the work that Black River had been doing for years in cutting its bed down to, and laying bare the country rock in almost continuous cross-section. Had it not been for the river bed the season's work could have yielded no great amount of information. But the state geologist saw the value of the river cut when he directed the party to take that field. The only exposures outside the river bed are on the hills and ridges spoken of above.

The first work done was to accurately survey and level the road, after which a pacing and barometrical survey was made of the district, using the road as a base line. The iron quarter-pin between S. 4, T. 47 N., R. 46 W. and S. 33, T. 48 N. R. 46 W. was used as an initial station for the transit work. This station is two miles from Bessemer.

The distance along the road from the initial station to the lake is 13.34 miles while the direct distance between the same two points is 11.06 miles. A traveller on the road two miles from the initial station is 1.63 miles to the west of it. The lake end of the road is 0.83 miles to the east of it. While the road does not follow the river closely it takes the same general direction.

On the whole the road is fairly level and retains its elevation until within two and a half miles of the lake. The initial station of the transit line was used also as a bench-mark and is 685 ft. above the lake. Another point about two and a half miles from the lake is 600 ft. above it, so that there is a decline of only 85 ft. in the first 11 miles. In the remaining distance there is a fall of 600 ft. the last 100 being the height of the lake hill. On the whole, the road has not many hills, and no very bad ones, save that just spoken of, which is steep. The next largest is just south of the D. S. S. & A. E. Ry., and is one which Bessemer people have to go over in going to and from North Bessemer which is their passenger station for the D. S. S. & A. R. Ry. This hill is also just 100 ft. high but is not so steep as the lake hill.

Bessemer is on the Gogebic iron range, and is underlain by rocks of that series, but the ridge just to its north exposes Keweenawan rocks. The nearest Penokee exposures to the Keweenawan rocks are gray-wackes, which strike nearly east and west and have a dip of 55° to 60° N.

The first exposures above the graywacks are of red sandstone, whose vitreous appearance makes it somewhat resemble a quartzite. This sandstone is the basal member of the Keweenawan series.

The work of geologists, such as Van Hise in his Penokee-Gogebic monograph puts an unconformity between the iron-bearing and the copper-bearing rocks above them. The exposures near Bessemer do not warrant the saying that there is an unconformity, nor do they warrant the saying that there is not. The rocks are not exposed along the contact, there being a width of at least one-half mile unexposed. Concerning conformity, or unconformity, one can say nothing from the area worked by us.

The basal sandstone of the Keweenawan dips 70° to 73° N. There is a surface exposure of 200 ft. How much of the drift covered area is underlain by sandstone, and how much by graywacke cannot be said.

Above this sandstone is a thick series of eruptives. The sedimentaries of the Penokee and the basal sandstone of the Keweenawan represents a period of quiet, but the great thickness of eruptives in the base of the Keweenawan marks a change. There is exposed almost continuously a surface width of 8600 ft., which with a dip of 70° means a thickness of 8000 ft. of eruptives. Following is a surface width of 13000 ft. without exposure. Since the dip gradually decreases as we go north it is not at all probable that this area is underlain by rocks that have an average dip greater than 65°, which would give a thickness of 11800 of rock. This area is probably underlain by eruptives, since such rocks are exposed on either side, yet it is not at all certain that there are not some sedimentaries. Beyond the unexposed area are eruptives with a surfaced width of

19000 ft., which if we allow to dip of 56° N., gives us a thickness of 15600 ft. Here then is a total thickness of 35400 ft in which the rocks are practically wholly basic eruptives.

Above these basic eruptives is a felsite whose exposed width is 660 ft., and it cannot exceed 2000 ft. The known thickness is 460 ft., since its dip is 45°, and it cannot exceed 1400 ft. The resisting power of this felsite has enabled Chippewa Bluff to stand against the degrading agencies of nature.

Above the felsite there is a series of interbedded sedimentaries and eruptives. These have a surface exposure of about 9000 ft. With an average dip of 37° there is a thickness of 5400 ft. The top of these interbedded eruptives and sedimentaries takes in the last eruptives exposed and probably marks the top of Irving's Lower Keweenawan.

Above this point only sedimentaries occur, and their exposures on the Black River show them to be conglomerates sandstones and shales.

I shall consider these rocks briefly under the heads that I have outlined above. There is no real reason why such a division should be made, except for the sake of convenience in this present paper, and yet the division can no doubt be excused since there is represented in each a difference in the way in which nature has displayed hereself.

1.	Basal sandstone	200 ft.
2.	Eruptives with little or no sedimentary rock	35400 ft.
3.	Felsite with a known thickness of 460 but with a possible	1400 ft.
4.	Interbedded sedimentaries and eruptives	5400 ft.
5.	Sedimentaries	1500 ft.
	Total	43900 ft.

1. The basal sandstone: I shall not add anything to what I have already said about this sandstone.

2. Eruptives with little or no sedimentaries: At the base there are amygdaloidal with amygdules mostly of quartz, many of which are agate. Above them are labradorite porphyrites with small phenocrysts of feldspar. Not far from the base is a thin bed of very coarsed grained gabbro. Its presence is interesting since it is, I think, the first exposure of the Bad River gabbro noted in the Keweenawan of Michigan. In all probability it is a sill. Above the gabbro there is a series of flows partly melaphyres, and partly labradorite-porphyrites. There are, in all, several flows of these poryphyrites one of which has phenocrysts of feldspar 30mm. in length. About 7,500 feet from the base of the Keweenawan there is a thin felsite-porphyrite and above it are exposures of ophite. Then follows the space without exposure which is here being considered as containing eruptives only. It is possible, though not probable, that there is considerable sedimentary rock in it. Beyond this drift covered part is a series of lustre mottled melaphyres. Some have mottling as much as an inch across but the most of the mottling is much smaller. These ophites continue almost up/to the Chippewa felsite.

This body of eruptives is not wholly without sedimentaries for there are some sandstones just beneath the felsite and at least one bed farther down with a thickness of 100 feet. But it is quite certain that the sedimentaries are small factors. It is interesting to notice here that although the great mass of Keweenawan rocks up to this point are basic, yet what few sedimentaries are present are acid.

There does not seem to be any flows of very great thickness in all this great body of eruptives. At the very base where the rock is well exposed on the Bessemer bluffs the different flows are readily distinguished and they show different thicknesses from 10 up to 250 feet. It is quite certain that the larger lustre mottling in 21-48-46 is indicative of thicker flows, as is also the coarser grain of the rocks on the highlands to the east of Chippewa Bluff. But it seems quite evident that there are no very thick flows.

Where the rock is well exposed it is quite common to see a thin seam of sandstone, sometimes as much as two inches thick, between two flows. Also where pockets are formed in the top of the flow, as they sometimes are, they are filled with well stratified sand. These things would seem to indicate that these Keweenawan flows occurred under water.

3. Felsite: Above this thick mass of basic rocks which is almost wholly of eruptive origin is a felsite flow. I shall call it in this paper the Chippewa felsite. It has a dip of 45 °N. and a strike of N.80°E. It is certainly 460 feet thick, and, as there is a space above it without outcrop, it may have a thickness of 1,400 feet. But, since there are so many thin strata beginning to appear at this horizon, it would be simply a guess to say what rock fills the gap. The felsite may continue across it, the conglomerate above may extend down through it, or it may contain basic eruptives. The felsite is not unlike that composing some of the pebbles that occur in the conglomerates above it.

There are outcrops of this rock only in Black River and on Chippewa Bluff. In the latter place it forms the cap of, but not the whole hill. For at least two-thirds of the way up the south side there are exposures of ophite, and before reaching the felsite there are some thin beds of sandstone and a small amount of volcanic material.

The felsite has a fine grained chocolate brown ground mass, and carries phenocrysts of orthoclase and quartz.

4. Interbedded sedimentaries and eruptives: The thickness is placed at 5,400 feet, but it may be greater, since a part or even the whole of, the space without outcrop may be underlain by these rocks. If so this division would extend downward about 1,000 feet more than is here indicated.

This division contains sedimentaries and basic eruptives. The former have so increased in proportion to the latter that one cannot help but notice the difference from the great thickness of eruptive rocks below the Chippewa felsite. Below the felsite the per cent of sedimentaries is practically nothing, but from it up to the top of the last eruptives they form about 25 per cent of the rock. The per cent of sedimentaries increase as we go upward in the division itself.

Some of the eruptive beds contain five or six flows, and some less. They are, for the most part, ophites. The lava flows are all thin, mostly under 150 feet, and the average thickness would not exceed 100 feet. All have amygdaloidal surfaces. The weathering seems to be much greater in these flows than in those below the Chippewa felsite. The amygdules are largely calcite, chlorite and laumontite.

There are at least six sedimentary beds in this division, and all are composed of acid material. Sometimes these beds are purely sandstone, and sometimes conglomerate. Others show both phases. There is a great variety of pebbles but the felsite

pebbles form nearly the whole mass. The highest sedimentary bed of this division is a conglomerate 400 feet thick. The highest eruptive bed is 350 feet thick, and marks the close of the eruptive action of Keweenawan times. The top of this eruptive is probably the top of living's Lower Keweenawan.

5. Sedimentaries only: The highest division that is made in this paper contains sedimentaries only. The rock at the base of the division is a conglomerate. Some of the boulders are nearly a foot and a half in diameter, and from these there are all sizes down to the smallest sandstone grains. All the pebbles are water-worn and well rounded. There are pebbles of amygdaloid, granite, diorite, syenite, quartzite, jasper, labradorite-porphyrite, and felsite-porphyrite, but all these are few in number and it is putting it quite strong enough to merely say that they are present, for nearly the whole mass is made up of different varieties of felsite pebbles and boulers. The finer material between the pebbles is also acid. As we go upward we find that the conglomerate gradually changes to a sandstone, and the last 300 feet shows no conglomerate at all except a thin band of 10 feet about 50 feet from the top. The sandstone has a red color, but in some places it is quite brown. All through it there are seams of white sandstone varying in thickness from a quarter of an inch up to one foot. It has a marked tendency to split along its bedding planes, cleaving almost like shale, and for this reason will never be of value as a building stone.

Above this thick conglomerate bed is the Nonesuch formation. Only the lower contact is exposed on the Black River and that at the very mouth. About five miles westward on the lake shore the upper contact is exposed, and the shale is seen to have a thickness of not more than 300 feet. This formation displays the typical greenish colored Nonesuch shales interbedded with Nonesuch sandstone. These are the youngest Keweenawan rocks exposed on the Black River.

The rocks described above are all exposed in the Black River section, and the thicknesses given here are calculated from the exposures in that section. Irving says of the Lower Keweeawan in his monograph on the copper-bearing rocks vol. V, U. S. G. S., p. 158, "On the Montreal river, taking the surface width and dip angles together, the apparent thickness is as much as 33,000 to 35,000 feet, but how much of this may be due to the continuation westward of the Keweenaw fault, or whether this fault extends so far as this, it is impossible to say. It certainly does not extend much farther and, from its evident rapid decrease in throw from the Ontonagon River westward, it seems that its influence on the Montreal cannot be great." At the base of our section the Montreal is about six miles west and at the top it is as much as eighteen miles. The thickness of the Lower Keweenawan on the Black River appears to be as much as 42,000 ft.

The section that was made on the Black River was small and does not warrant any very general conclusions, but there are a few points that may be noted.

There are no very thick flows in the Keweenawan as it is exposed in this section, nor are all of the flows alike lithologically. In the great eruptive division below the Chippewa felsite there are melaphyrs, ophites, labradorite-porphyrites, and felsites, and, indeed, almost every degree of acidity is displayed from the labradorite-porphyrites up to the felsite-porphyrites. All of the flows have amygdaloidal surfaces and massive centres, and most of them have pipe amygdules at the base.

Keweenawan time seems to have been inagurated quietly as is indicated by the basal sandstone. Soon, however, it displayed itself more violently, and lava flow after lava flow followed one another building up a great column of eruptives. Some of these flows seem to have followed each other in rapid succession, and again, a little time seems to have elapsed as is indicated by the thin seams of sandstone between some of the flows. The great eruptive period did not end as suddenly as it began for the sedimentaries become gradually more and more prominent as we ascend in the series. This prominence is displayed in the increasing frequency and greater thickness of the beds.

It is a very striking fact that all of the sedimentary rocks save the Nonesuch, no matter whether above the Chippewa felsite or below, are strikingly acid, and all resemble each other very much. The great mass of the building material of the aqueous rocks is felsite. The Nonesuch is basic and it is worthy of note that there is a sudden change from an acid sandstone to the basic Nonesuch.

At the base of the Keweenawan there is a very high dip, about 70° N. As we go toward the lake it gradually decreases so that at the mouth of the river there is a dip of not more than 25° N. The strike does not materially change, lying always between N. 70° and 80° E.

It does not, on the whole, seem that this change of dip is the result of tilting during Keweenawan times. If so the basic rocks would surely take a more important place in the building up of the great conglomerate beds. It is quite true that the basic pebbles would wear down rapidly, but, at any rate, the finer material between the pebbles would be basic; but it is not, it is acid. There are, however, a few of these basic pebbles present, but it seems to me easier to explain the presence of these pebbles without the tilting in Keweenawan time than it is the absence of basic material if the tilting took place during Keweenawan times.

The amount of felsite in the sedimentary rocks is enormous when compared with the amount in place. It seems quite certain that all of this material could not come from the felsite beds in sight. It seems more probable that there were originally great felsite knobs that have been worn away.

Again, there must be a reason why so much basic material began suddenly to be laid down at the beginning of the Nonesuch formation. It is at least suggestive of a time break, and that the base of the Keweenawan is being exposed and subjected to degredation.

Before leaving the rock descriptions I wish to call attention again to the fact that the divisions made above are merely for the sake of convenience in this present paper. The name "Chippewa" felsite is used in the same manner.

In the first part of the paper great north and south gaps were spoken of as breaking through the ridge near Bessemer. This ridge has in it several characteristic beds such as felsite-porphyrites and labradorite-porphyrites. The identifying of these bands is an easy task, and the identification makes it quite evident that there are at least four dip faults in the area worked.

Lying immediately north of Bessemer is a gap, at least a mile wide, through the ridge. The rocks are well exposed on either side, and a throw of about 1500 ft. is easily proved. West, about a half mile, from this gap is another fault with a throw of about 75 ft. The evidence of this fault is shown by the rocks exposed about three-eights of a mile south of quarter-pin 4-9-47-46. About 300 ft, west of the rocks are thrown in the opposite direction about 125 ft. The stream bed of Powder-Mill creek lies in the line of weakness of another fault, the beds on the west side of the stream being shifted between 400 and 500 ft. north of those on the east side of the stream. Again in 6-47-46 there is evidence of a fault with considerable throw. In all these cases the west side is thrown north. These faults cause a line of weakness along which the rocks are easily weathered away, hence the gaps through the ridge.

There are evidences of faulting along the bed of Black River, slicken-sides and fractured rock being very common. In one place, 28-48-46, there is a very prominent fault-breccia. In no place in the river bed is there any evidence of the amount of throw. It is always evident that the fault plan is nearly north and south.

The Nonesuch shale is well exposed, west of the river mouth, along the lake shore, but it shows no ready evidence of faulting.

It is possible that the bed of Maple Creek is along the line of weakness caused by a fault.

The general surface of the country is about 600 feet above Lake Superior. The Bessemer ridge, Chippewa hill, the eastern highlands and the conglomerate ridge are all about equally high and are between 200 and 300 feet above the surrounding country. Except these elevated portions the' country is generally level. The lake front is marked by terraces the first being about 100 feet. Behind it the country generally rises, so that with a distance of two miles the general elevation is reached. The lake has banks of red clay from 90 to 100 feet high, along whose base is a narrow bench.

Over the whole area there are numerous swamps of cedar and alder. A great deal of the land is swampy and would be very difficult to traverse during the wet season, especially the western part of the area worked.

In the last three miles of its course Black River has held pretty permanently to its present bed, but above that it has wandered considerably, and has cut out a valley of some width. For the most part there are thick cedar swamps along both edges of the river but in some places it is cutting into the foot of the bank.

The whole country is covered with glacial till, and in many places there are numerous large boulders in the soil. Of the fifty square miles of area covered by the party at least forty are fit for cultivation. Most of the land is second rate and, indeed, some is third rate, but there is a small amount which is first rate. However, before being put under cultivation, much of it would require to be drained. There are some farmers near Bessemer, and where they have cleared the land they have good looking farms. I do not know how much they produce annually, but they appear to be getting on well, quite as well as many farmers in Southern Michigan. The winter season is long, of course, and the summer short and with the danger of late frosts in the spring, and early frosts in the fall, there is a limit to the kinds of grain that can be produced. It is certain too, that it must be difficult and expensive to feed stock through a winter so long and cold. I do not know that I could advise any person to take up a farm in the district, for there is yet much land in the United States which is more easily put under cultivation, and is more valuable. At the time, I must say that it is possible to live on this land, and live well too. If the time comes, .and come it must, though probably not soon, when the people of the United States are being crowded for room such districts as this, although now only a wilderness, will support many people.

The country is covered with hemlock and maple chiefly, but there is a small amount of pine and spruce. In some places the timber is small and without value, as in 29 and 30 48-46, which have practically nothing but small poplar and spruce, mostly about three inches in diameter, and so thickly grown together that it is difficult to get through. There is a great deal of small cedar in the swamps.

In 18-48-46 there is a large peat bog covering at least a half square mile. The peat is generally about six feet thick. There are several other smaller peat bogs some on the west side of the river, and some on the east. There is no doubt that they will produce much fuel when the time comes that it is required.

Black River has many falls and rapids, and is capable of yielding a great deal of power. Even in the low water season of August there is considerable water in the river.

It is difficult to say whether there will ever be any copper mining in the western part of the Michigan Keweenawan. There does not appear to be any geological reason why copper should not be present as on Keweenaw Point. Copper is present in Western Michigan but it has not been found in quantity. Some of the rock from 3 and 4-48-46 showed small particles of copper but the showing was only small.

There have been some attempts at mining. Several years ago, in fact before 1850, some tunneling was done in the side of Chippewa hill. More recently an attempt was made by the Old Peak Mining company on the same hill and in 34-49-46 but without success.