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BY
GEO. D. SHAFER
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BY AUTHORITY

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LETTER OF TRANSMITTAL.

TO HON. CHASE S. OSBORN, *Governor of the State of Michigan:*

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

Respectfully,
GEO. D. SHAFER,
Secretary of the Michigan Academy of Science.
E. Lansing, Mich., May, 1911.

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SOIL AND SOIL PROBLEMS FROM THE STANDPOINT OF PHYSICIST.

J. A. JEFFERY.

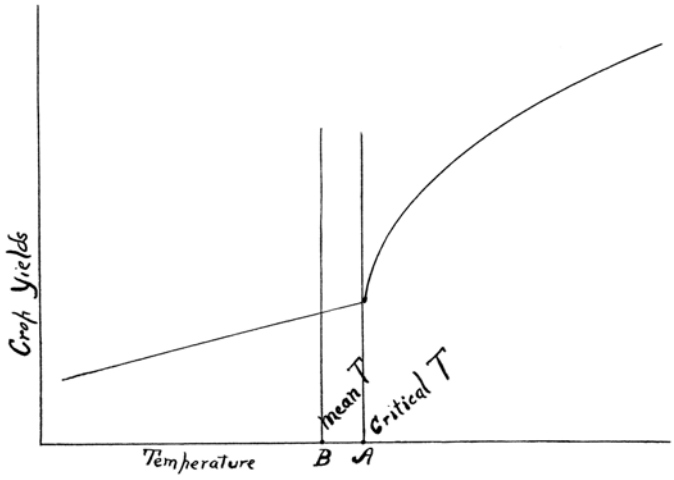


FIG. 1.

So long as soils produce moderate to large crop yields, their productiveness does not arouse much concern, it is not taken, seriously. When the yields reach a point so low as to be unprofitable or but moderately profitable, the question "why" is asked. Not long ago this question was thought not so hard to answer. It was generally conceded that the supply of plant food was being exhausted. The remedy was as simple and about as correct as the answer:—The supply should be replenished.

For a time the replenishing worked, and it does yet under certain conditions. Under other conditions it does not. The result is that other "whys" are introduced until at the present time the whole thing is given another name. It is a *soil problem*, and a many sided one.

It was thought at one time that the solution of the problem lay with the chemist, but he failed to produce a satisfactory solution, and as the problem is further studied it is suspected that the botanist, the bacteriologist, the soil physicist and the practical crop and fruit man may each be required to assist not only to determine the causes, but also to decide upon the theory and the facts of the remedy.

Two soils are here offered by way of illustrating the reasons or some of the reasons at least for the foregoing conclusions.

These two soils were taken from adjacent fields. In appearance they are very similar—practically identical. They did not appear so 18 years ago: That year the soil numbered 1 produced 42 bushels of wheat per acre, last year it produced 18 bushels per acre. Eighteen years ago the soil numbered 2 produced 12 bushels of wheat per acre, last year it produced 36 bushels per acre. Eighteen years ago the soil numbered 2 was called a “blow” sand. At the present time it does not blow. Its moisture condition does not permit it. When the present owner purchased this land 19 years ago he was laughed at for his alleged folly. He had faith in the soil however, and in his ability to make it a profitable soil and his faith has been abundantly rewarded.

The transformation has been brought about without the use of mineral fertilizers. The owner has read, observed and thought.

He has practiced care in the selection and use of tools.

He has followed a fairly careful rotation of crops—one in which clover formed an important part.

He has grown one "money crop" each year—wheat, or potatoes or beans.

He has built up a dairy herd in addition to keeping other live stock, and has exercised fair care in husbanding and applying the manures produced on the farm.

In other words he has followed a fairly rational system of soil management (practice).

The farm from which the soil numbered 1 was taken has been rented during the greater part of the period. Further comment is hardly necessary.

Two important facts are before us. First: The larger part of Michigan soils are producing abnormally low yields and in not a few cases negatively profitable yields. Second: In a goodly number of cases soils producing very low and even unprofitable yields have been transformed into highly productive soils, and that without the addition of mineral fertilizers. In general the transformation has been accomplished by means similar to those applied to the soil numbered 2 above.

We ask then what are the causes of this lowering of yields?

Are they chemical, physical or biological, and whatever the direct cause, may it be due indirectly, the soil physicist will ask, to the failure of the soil to function normally physically and if so how great is the departure from normal?

Is the departure measurable?

If measureable, how far does the departure affect
- chemical changes,
- the abundance and activity of life forms,
- solutions,
- surface tension,
- osmosis,
- transpiration, and
- deposits and retention of the by-products of plants

and how far do any of these become causes as well as effects?

The fundamentals to crop production so far as the soil is concerned are:

- Proper temperature
- Proper moisture
- Proper ventilation.

In this soil investigation work the Soils Department is attempting to make a study of

Temperature

As modified by other conditions { Physical, Etc.

As a modifier of other conditions { Physical, Etc.

As an index of other { conditions, activities, { Physical, Etc.

(The relations other than physical are to be studied co-operatively)

Some of the questions presenting themselves are:

I. What is the normal temperature for the different types of Michigan soils, (under normal conditions)?

II. How far does any individual of a type, as the soil numbered 2, fall below normal?

III. How far may proper farm practice raise the temperature toward normal or above normal, which may be desirable,—is desirable in most cases?

IV. How far may such rise In soil temperature affect crop production?

A good deal has been discovered and written already concerning soil temperatures and it may be questioned whether this data already found might not be used In this experiment.

It is a fact which is coming more and more to be appreciated that the facts apparently controlling the temperature in one soil may not be effective in the same direction and to the same degree in another soil. It is true also that much of the data, already found may have been improperly interpreted and even improperly presented in our Agricultural literature.

It is commonly set forth that the application of manures to the soil has the effect of raising the temperature and this rise of temperature is credited quite largely by some writers to the fermentations taking place in the manure thus added. Experiments conducted at this station show that an application of ten tons of manure per acre worked to a depth of six inches into the soil *when apparently no other influences are at work* results in a temperature rise of about 0.15 degrees F. In sunshiny weather the temperature of the soil receiving this ten tons of manure per acre is raised over two degrees, apparently because of the increased capacity of the soil to absorb the sun's heat. For the reasons named above, we deem it advisable to make a careful study of the details of soil temperature.

A very important question that has suggested itself, is the possibility of what might be called a critical soil temperature, beyond which the result in crop yield may Increase very rapidly. It must be admitted that the question strictly speaking is but a hypothetical one and yet there is ground for such question. Fig. 1 illustrates the idea. The horizontal dimension represents temperature, while the perpendicular dimension represents crop yield. A. represents the theoretical critical temperature. The curve of yield which may be a straight line to the left of the critical temperature becomes a rapidly ascending curve beyond the point A. If B. the mean temperature of the soils stand fairly close to the critical temperature it may be possible by proper methods of soil management to raise the mean temperature beyond the critical point. The benefits are represented by the rapidly ascending curve. There are numerous means at hand by which the farmer may materially improve the temperature of his soil.

If there be such a critical temperature it may be that this critical temperature will prove an average mean. If however, it should prove to be a mean of maximum temperatures the question becomes a more important one. It is barely possible this critical temperature may prove to be the extreme maximum, that is the highest temperature that is at any time. Then the question becomes even more important yet.

If there be such a critical temperature it makes little difference whether it be a direct cause or whether it be an indirect cause acting one to a dozen phenomena.

Michigan Agricultural College, East Lansing, Mich., April, 1911.

SOIL AND SOIL PROBLEMS FROM THE STANDPOINT OF THE CHEMIST.

A. J. PATTEN.

From the standpoint of chemistry the soil is a conglomerate mixture of definite inorganic compounds resulting from the disintegration of rocks, together with the organic remains of plant and animal life in various stages of decomposition, water and gases.

It was early supposed that all the changes taking place in the soil were chemical in their nature, it was also believed that all the phenomena of plant growth were essentially chemical. The following quotation is taken from Johnston's Agricultural Chemistry: "The art of culture indeed is almost entirely a chemical art, since nearly all its processes are to be explained only on chemical principles. If you add lime or gypsum to your land, you introduce new chemical agents. If you irrigate your meadows, you must demand a reason from the chemist for the abundant growth of grass which follows." Thus, according to Johnston the knowledge of soil conditions was only limited by the lack of knowledge of chemistry.

About the middle of the nineteenth century Liebig formulated his theory which he expressed in the following four laws:

First—"A soil can be termed fertile only when it contains all the materials requisite for the nutrition of plants, in the required quantities and in the proper form."

Second—"With every crop, a portion of these ingredients is removed. A part of this portion is again added from,

the inexhaustible store of the atmosphere; another part, however, is lost forever if not replaced by man."

Third—"The fertility of the soil remains unchanged if all the ingredients of a crop are given back to the land. Such a restitution is effected by manure."

Fourth—"The manure produced in the course of husbandry is not sufficient to maintain permanently the fertility of a farm. It lacks the constituents which are annually exported in the shape of grain, hay, milk and live stock."

The promulgation of this theory naturally placed an added emphasis on the value of the inorganic plant-food constituents and it was believed that with the results of a chemical analysis of a soil it would be possible to determine its crop producing power and likewise its fertilizer requirements. However, it soon became evident to agricultural chemists that there was no definite relationship between the productive capacity of a soil and its content of nitrogen, phosphoric acid and potash.

Many people, however, today believe that the chemist needs only to make an analysis of a soil in order to advise the proper kinds and amounts of fertilizer to be used and I fear that this idea is being encouraged by some soil investigators.

The amount of so-called plant-food in the soil is only one of the factors governing its productivity, other factors are organic matter, moisture, drainage, cultivation, climatic conditions, etc. Each of these factors is as important as the amount of plant-food, because each has a determining influence upon the crop production and also upon the availability of the plant-food in the soil.

Availability is a convenient term which the soil investigator has used very largely in the past and is using today for describing a condition of things about which we know scarcely anything. We say that the plant-food must be available before it can be taken up by the plants. The truth of the statement will in all probability never be questioned. But the vital point is, what constitutes availability or in other words in what form, must the plant-food be before it can be taken up by plants?

The one requirement is, that it must be in solution in the soil water. The soil solution, however, is not a simple one, but, on the other hand is very complex and is influenced by many factors. These many factors are so closely inter-related that any slight change in any one of them is sure to change this relationship and it is impossible to predict, at least with our present knowledge, what influence the changing of any of these factors may have upon the composition of the soil solution. Many attempts have been made to extract the soil solution as it exists in the soil but the attempts have not been generally successful owing to mechanical difficulties. It is probably true, however, that the composition of the solution would not be the same in any two soils in respect to all conditions and it is also quite certain that the composition of the solution in any given soil changes from day to day within certain narrow limits.

Many methods have been proposed; for determining the availability of the inorganic plant-food in the soil. These methods, have mostly been based upon the relationship between the amount of the inorganic plant-food constituents extracted from the soil by the solvent medium and that taken from the soil by the crop. Maxwell proposed a 1% solution of aspartic acid on the ground that the organic acids of the soil are amino acids and that they influence the availability of the inorganic constituents. Dyer recommended the use of 1% citric acid because he supposed it bore a near resemblance to the methods of solution of plant-food in contact with the rootlets of plants. Moore of the Bureau of Chemistry after several years of experimentation proposed a solution of HCl of N/200 strength.

Many other methods, too numerous to mention, have been, proposed. None of them, however, had any sound scientific basis for their acceptance, but were proposed because those who stood sponsor for them, observed that with one particular crop grown upon one particular soil there was a relationship between the amount of plant-food extracted by the particular solvent medium and that removed by the crop.

All attempts! to adapt these methods .for universal application have resulted in failure and when we consider the variation in soils and the great difference in the feeding powers of different crops, the variation in climatic conditions, seasons, drainage, cultivation, etc., it is extremely doubtful if any arbitrary method will ever be devised that may be relied upon to determine the available plant food in all soils.

Although a large part of all the known elements are found in soils, only about 14 are vitally connected with the living plant and it is the general belief today that only three and at most four of these, nitrogen, phosphorus, potassium and calcium need demand the serious attention of the agriculturist. The amounts of phosphorus, potassium and calcium in virgin soils depends largely upon the composition of the rocks from which they originated. The amount of these elements in cultivated soils depends also upon the manner in which the soils have been handled.

The nitrogen has practically all been introduced into soils since their formation and it is extremely fortunate that this most expensive form of plant-food may be, in a great measure, supplied to the soil by a due attention to the practice of crop rotation. It was originally supposed that only the inorganic forms of nitrogen, phosphorus and potassium could serve as plant-food and many attempts have been made to classify soils as good or poor on the basis of their content of these elements. Maercker of the Halle Station, Germany, has made the following classifications:

Grade of Soil.	Potash.	Phosphoric Acid.	Lime.		Total N.
			Clay Soil.	Sandy Soil.	
Poor	Below 0.05	Below 0.05	Below 0.10	Below 0.05	Below 0.05
Medium	0.05—0.15	0.05—0.10	0.10—0.25	0.05—0.15	0.05—0.10
Normal	0.15—0.25	0.10—0.15	0.25—0.50	0.15—0.20	0.10—0.15
Good	0.25—0.40	0.15—0.25	0.50—1.00	0.20—0.30	0.15—0.25
Rich	Above 0.40	Above 0.25	Above 1.00	Above 0.30	Above 0.25

Other investigators), notably Hilgard, have made similar attempts to classify soils but there is no unity of opinion on this point. It is not at all strange that there should be this wide difference when we consider that the amount of the so-called plant-food is only owe of the many factors governing the productive capacity of the soil—other factors are drainage, cultivation, climatic conditions', seed selection, etc.

Although it has long been recognized that organic matter is a great asset to the soil but little has been definitely learned in regard to its nature and composition. There is a tendency on the part of most soil experimenters to associate soil organic matter with the term humus. Many consider them to be synonymous, others consider humus to be composed of definite compounds produced by the decomposition of organic matter and that there might be organic matter present that had not yet reached the state of humus. At the present time the term humus is generally used to designate the product obtained by treating an alkaline extract of a soil with an acid.

As early as 1844 Mülder made an extensive study of the organic matter of soils and claimed to have isolated seven distinct compounds to which he gave the following names: crenic acid, apocrenic acid, geic acid, humic acid and humin, ulmic acid and ulmin. He also gave to these bodies definite chemical formulae. A little later Grandeau developed his method for separating humus which is essentially the one in use today.

As the number of investigators on the subject of humus and organic matter increased, more or less controversy arose as to the composition, of some of these supposed definite compounds. Different investigators could not agree upon the composition of humic acid obtained from soil nor could the same composition be obtained for humic acid derived from different materials. Later a controversy arose over the question as to whether nitrogen was a constituent part of the humus or not. Some claimed that it was organically combined, while others claimed that the nitrogen was present as ammonium salts.

Without going farther into a review of the literature on this point it will be seen that the one thing which characterized the work of the early investigators was the lack of anything like concordant results. In fact the same lack of definite results has characterized the work of all investigators down to the present time who have followed in the footsteps of the early workers in their attempts to throw light upon this most interesting and difficult problem. Consequently there seems to be no valid reason why we should continue to use a method for determining humus, which, we must admit, removes not one compound but a mass of organic compounds about which we are only beginning to learn the least little bit. And furthermore it would seem to the writer that it would be a step in advance if we would discontinue the use of the term humus altogether and confine ourselves to the more comprehensive term—organic matter.

During the past few years much good work of a purely scientific character has been done on the organic matter of soils. Shorey, now of the Bureau of Soils of the United States Department of Agriculture was the first to isolate a definite crystalline compound from soil. This he identified as picoline carboxylic acid. Since then Schreiner and his associates have isolated several organic compounds, many of which have proved to be more or less toxic to wheat seedlings. Nearly all of the compounds isolated by these Workers have been free from nitrogen.

Nitrogen which is the most costly form of plant-food we have to consider, is present in the soil almost entirely in combination with organic matter and probably very largely in the form of protein compounds. If this is true, then the breaking down of the nitrogen compounds in the soil is largely one of proteolysis and one should expect to find many of the same compounds in the soil as results from the hydrolysis of protein compounds in the laboratory.

Suzuki digested humus with hydrochloric acid and from-the extract was able to isolate the following substances, long recognized to be decomposition products of protein: Alanin, Leucin, Aminovalerianic acid, Prolin, Aspartic acid together with traces of Glutamic acid, Tyrosin and Histidin.

Three years ago Jodidi working in the chemical laboratory of the Michigan Experiment Station began a study of the organic nitrogen compounds: in peat soils and from his work concluded that from two-thirds to three-fourths of the nitrogen extracted by boiling acids is in the form of monoamino compounds, about one-fourth in the form of amids and the rest is in the form of diamino compounds.

Jodidi did not succeed in isolating any individual compounds although he was led to believe that tyrosine was present in traces.

Mr. Robinson continuing the work of Jodidi has recently succeeded in isolating leucin and isoleucin from, peat soils after boiling with acids. Also, by adapting to his conditions the method for ammo nitrogen recently revived by Van Slyke, he has been able to determine with considerable accuracy the amount of nitrogen in these forms. In the samples of peat already worked with, the amount of ammo nitrogen after boiling with acid has been from 30-35% of the total nitrogen. Only traces of amino nitrogen are found in peat as such.

These compounds necessarily occur in soils in small quantities, and their separation is accomplished only after the most careful and painstaking work. But it is confidently expected that now since the way has been fairly well paved more investigators will be tempted to

enter this field of research and .more of these compounds will be isolated from soils.

Certain it is that with a more complete knowledge of the composition of the organic matter of soils one will be able to predict more definitely in regard to the possible availability of some of the plant-food elements in combination with it.

The relation of the soil phosphorus to the organic matter is perhaps less understood today than is the case with nitrogen. There has been a great diversity, of opinion as to the existence even of phosphorus in combination with organic matter. As early as 1844 Mülder observed that the organic matter was not readily freed from phosphorus. Grandeau believed that the phosphorus associated with the extracted *matiere noire* to be an index of the fertility of the soil. Eichorn concluded that the phosphorus does not form organic combination. Some experimenters believed that the phosphorus was held in the organic matter by absorption. Van Bemmelen supported this theory and he suggested that a part of the phosphorus occurred in the form of a "colloidal humus-silicate complex."

Schmoeger reviewing the work of his predecessors concluded that the phosphorus did not exist as absorbed phosphorus but that it was present in organic combination. He found lecithin to be present in traces and was led to believe that nuclein or some closely allied bodies were present. Asô confirmed in a general way, the results obtained by Schmoeger. He drew the following conclusions:

1. "Phosphorus exists in the soil as inorganic and organic compounds."

2. "The organic' phosphorus materials is principally nuclein with a small part of lecithin."

3. Ignition rendered the phosphorus in organic combination available."

More recently Schreiner and Shorey have demonstrated the fact that phosphorus does exist in the soil in organic combination by isolating several compounds known to be decomposition products of nucleo-proteids. Beyond the fact that the presence of organic matter in the soil improves its combination and also increases its productive capacity we know but little of the value of any of these specific compounds as possible sources of plant food. We know there are some organic compounds in the soil that are harmful and we need to know more in regard to the most practical means of counteracting them.

The manner of conducting fertilizer tests by measuring the crop produced has failed to materially increase our knowledge of soil conditions and it is now quite generally recognized that it is unsafe to draw general conclusions from results based on such experiments. If we accept the dynamic theory of soils, that is, that they are continually changing and that no two soils are alike, we must inevitably come to this conclusion. These experiments have, however, served a purpose, in that they have taught us the direction in which soil investigations of the future must lead. The introduction of a chemical substance into the soil changes the condition, not only in respect to the material added but to those already present. It also may and probably does affect the physical and biological condition as well as the chemical.

The method practiced by some experimenters of analyzing a soil sample representing the first eight or ten inches and from the results estimating the number of bushels of grain or the number of years that the soil will produce a certain sized grain crop before it becomes exhausted is unscientific and unsound. The time is now ripe when we should attack these problems in a truly scientific way.

While of course greater productive capacity is the ultimate aim of the soil investigator he should seek to find out and understand the changes taking place in the soil that accompany greater production.

Michigan Agricultural College, East Lansing, Mich., April, 1911.

SOIL AND SOIL PROBLEMS FROM THE STANDPOINT OF THE MICROBIOLOGIST.

OTTO RAHN.

Soil is to the physicist a mixture of particles of various sizes, as gravel, coarse sand, fine sand, silt, and clay. These particles have certain physical qualities, as absorption, heat conduction, water capacity, and pore space. The physical qualities of a soil are determined by the amounts and kinds of particles constituting it.

The chemist looks at soil problems in a different way. Soil appears to him as a mixture of soluble and insoluble compounds, of organic and inorganic matter. Some of the soil constituents are known to be plant foods, and to them the special attention of the chemist is directed.

To the microbiologist, soil is a medium for the development of a large variety of microörganisms. The domain of the soil bacteriologist is increasing rapidly, and the term bacteriology seems hardly broad enough, for a science that includes, besides the bacteria, yeasts and molds, even the single-celled animals,—protozoa.

In order to discuss the soil problems from the standpoint of the micro-biologist, it seems advisable to first state briefly the facts that are already established in soil bacteriology. Like the chemist and, the physicist, the microbiologist studies soil problems, ultimately from the viewpoint of soil fertility or crop production. From this viewpoint, microörganisms may be divided into those that are beneficial and into those injurious to crops. Of course, this distinction is not an absolute one, but it is helpful in classifying soil microörganisms according to their significance.

Microörganisms can be useful to plants in various ways, either directly by symbiosis, or indirectly by preparing

plant food. Symbiosis of higher plants with microörganisms is limited practically to the roots, but there it is a very common occurrence. The root-tips of the evergreens and of many other forest trees show quite regularly a growth of mold mycelium which is called mycorrhiza. Many other plants show mycorrhiza growth frequently, while with some it occurs only very rarely or not at all. There is no doubt that the mycorrhiza is of benefit to the' plants, though the relations between mold and host are not entirely explained as yet. It seems that the mold helps the plant to obtain food, either mineral matter or nitrogenous compounds. Perhaps, they fulfill different purposes in different plants.

Much attention has been given to another case of symbiosis, namely that of legumes with Pseudomonas radicicola, the bacterium of the root nodules. This symbiosis is so well understood that pure cultures of such bacteria are now grown commercially for inoculating the seed. It is at present the only case of a direct application of soil bacteriology. The subject is so generally known that it would be wasted time to discuss any details before this audience.

Far more important than the above mentioned direct relations between plants and microörganisms are the indirect relations, especially the preparation of plant food. Most soils contain plenty of plant food, but it is largely in a form unavailable to plants. Microörganisms attack decompose many of these compounds and especially nitrogenous compounds are made available almost exclusively by microörganisms. Thus, plant growth depends upon microbial activity in the soil.

Most attention has been paid to the changes in nitrogenous matter in soils. The nitrogen comes largely from dead leaves, plant roots, excreta, and remains of animals. These compounds are not directly assimilated by plants. They are readily decomposed by bacteria which break up the large molecules into smaller and smaller ones, until finally the nitrogen is in the simple form of ammonia. This may be assimilated by many plants, many, however, prefer nitrates, and they are accommodated by the nitrate-forming bacteria which oxidize ammonia to nitric acid. All of this microbial activity is named briefly "mineralization." The organic matter is, by the exclusive activity of microörganisms, changed to mineral compounds which alone can, be used by plants.

But the activity of soil organisms is not limited to the mineralization of organic matter. They also increase the nitrogen content of soils. Two groups of bacteria, the Azotobacter and the Clostridium are known to assimilate nitrogen gas from the air in order to build up their own protoplasm. It is believed that these organisms are necessary to keep the nitrogen content of soils which, would otherwise be decreased continually by crops, seepage, and denitrification.

The decomposition of nitrogen-free organic matter is also of considerable influence upon the availability of plant food. Cellulose, starch, and similar constituents of the plants are transformed by microörganisms to organic acids and carbonic acid, which will act upon insoluble minerals as calcium phosphate or magnesium, carbonate. Insoluble plant food thus becomes available to plants.

A very important product of the decomposition of organic matter has not been mentioned as yet, that is the humus. Very little is known about humus formation and it is mentioned here only because it is certain that humus is formed by microörganisms. How this is done and which microörganisms are essential is not known.

Bacteria, are further involved in the oxidations of hydrogen sulphide and of sulphuric acid. Iron compounds are also occasionally changed by microörganisms.

So far, only the beneficial organisms have been mentioned. They constitute by far the majority of soil organisms. But there are also harmful organisms in soil which injure crops either directly or indirectly. Direct injury is caused by all organisms of plant diseases. The rot of vegetables, the potato blight are a few examples of diseases caused by soil organisms.

The indirect injuries to crops caused by microörganisms are in connection with plant food. One group was much feared some time ago, namely the denitrifying. bacteria, which decompose the nitrates of the soil to nitrogen gas. Such denitrification means a direct loss of nitrogen to the field, but it is known now that it is rather unusual in a well ventilated soil. Another group of harmful organisms are the protozoa, which prey upon the essential soil bacteria reducing' their numbers and consequently soil fertility.

This is, briefly told, a bacteriologist's conception of soil. The object of this paper was to discuss soil problems rather than facts. It is, of course, impossible to enumerate in detail all the many points of interest in soil bacteriology. I shall try to present the most prominent problems which demand immediate attention. This introduces a personal element into the discussion, since not all bacteriologists value the same problems alike. If I speak of important problems, I mean those that are considered to be of vital interest by the laboratory which I have the honor to represent.

A problem that is at present taken up from different sides is that of the humus. The formation of humus has been studied very little, despite its significance, because of the insufficient chemical technique of its analysis. Efforts have been made recently by the Bureau of Soils to obtain a more definite idea of at least some of the many humous bodies, and it can be hoped that before very long humus will be known as a fairly well defined group of organic compounds. The bacteriologist's task is to find the organisms that form humus, and to study their habits and their food requirements. This knowledge will enable us to increase humus formation where it seems necessary and to prevent it, when desirable. The humus problem also includes the destruction. The organisms breaking down humous compounds to ammonia are very important because while not available itself, humus

yields decomposition products which are the most valuable plant food, namely ammonia and nitrates. By obtaining a perfect knowledge of the humus-forming and the humus-destroying organisms, we gain control of the humus content in soil.

The peat problem, or more definitely the use of peat as farm soil or as fertilizer is nothing but a side line of the great humus problem. Though there is undoubtedly a great difference between peat and humus, it seems quite probable that the solution of one problem will make the solution of the other an easy task.

Another problem is the constancy of the number of bacteria in soils. This factor may not seem very important to the superficial observer, but it has doubtless close relations to soil fertility. In decaying organic matter, in fermenting liquids, in sewage, and in milk the number of microörganisms will first increase rapidly, then decrease and in a comparatively short time most of the organisms are dead. In a given soil the number of bacteria is practically constant. Slight fluctuations are caused by seasonal influences, by rain and drought, by fertilizers, but the soil soon regains its original number of microörganisms. The old explanation of the constancy as an equilibrium established between the various kinds of microörganisms is not satisfactory. If such an equilibrium, were possible at all, it would be found in liquids too. But that is not the case. There may be an equilibrium between bacteria and protozoa, but we have no accurate knowledge as yet of soil protozoology. The constancy of the bacterial flora in soil is very important because it renders possible the immediate decomposition of organic matter entering the soil. In solution, where the organisms die after having acted for a short time, the decomposition soon comes to a standstill. In soil this does not seem to be so, at least, the limit is much wider. The faster and more complete decomposition in soil cannot be explained by drainage water, removing the harmful products and thus giving bacteria a new chance for activity. Drainage water contains very little organic matter which is of a nature that it could not possibly cause any retardation of microbial action.

This leads to another problem which is perhaps the most prominent one of today, namely the difference of microbial action in soil and in solution. It seems strange that until a few years ago soil bacteriologists paid no attention whatever to the physical structure of soil and carried on all experiments in solution. The dairy bacteriologist grows his organisms on milk or milk products, the veterinary bacteriologist grows bacteria for experimental purposes in the animal body, while the soil bacteriologist does not use soil as a basis for his soil experiments, but meat media and occasionally soil extract. It is very true that there is not much difference chemically between the so-called soil solution which is the natural habitat of soil bacteria and between a soil extract. Not the chemical qualities, nor the amount of food make the great difference between soil and soil solution, but the physical nature of the two. Bacteria live only in liquids. In soils, the liquid is spread in a thin film over all the finest soil particles, and thus the surface is many hundred times enlarged. Doubtless, other soil qualities, like absorption, influence microbial development, but no other factor has such an enormous influence as the exposure of a large surface of liquid to the air in a well-aerated soil. The abundant supply of oxygen is a great stimulus for aerobic bacteria, while anaerobic organisms are decidely suppressed. This can be illustrated by a few experiments in which quartz sand has been used instead of soil in order to eliminate the possible influences from any organic or inorganic soil compounds. A peptone solution was sterilized in a flask and inoculated with a bacterium that formed ammonia from peptone. The same amount of the same solution was mixed with some pure sand, sterilized and inoculated with the same pure culture. After 7 days, ammonia was determined in both cultures, and the sand culture had formed three times more ammonia than the ordinary liquid culture, from the same amount of peptone. With two other bacteria, five times and eight times more ammonia was formed in the sand cultures. Evidently these bacteria required plenty of oxygen, since the large supply of air caused an increase of ammonia production of 200 to 700%. A similar experiment was carried on with the nitrogen-fixing Azotobacter, which gave in sugar solution 4.2 mgs., in sugar solution plus sand 35.0 mgs. of nitrogen, the increase caused by sand being 720%. While aerobic bacteria are thus stimulated by the change from liquids to soil, anaerobic organisms are retarded in their development. Bacterium lactis acid was found to make only about half as much acid in milk, if quartz sand was added to the milk. Similar is the experience with denitrifying bacteria which were feared so much because they destroy nitrates. They are feared no more, for the experiments leading to their discovery were not properly conducted. They are found in most soils and they will destroy nitrate if the soil is submerged in a solution, but they will not attack nitrates at all in a well-aerated soil. Koch and Pettit showed recently that in soil with a fair moisture content, nitrates are not destroyed because the oxygen from the air is more readily used by the organisms than the oxygen from the nitrate.

These examples will suffice to emphasize the previous statement, that soil problems must be studied in soil and not in liquid media. Since the development of anaerobic bacteria of the soil is greatly increased in solutions, while aerobic organisms are suppressed, it is obvious that changes taking place in solutions allow of no conclusions whatever in regard to changes in soil. We must necessarily expect erroneous and even contradictory results if we neglect variations of 700%. Strange to say, bacteriologists have, until quite recently, paid no attention to this difference. This serious error has been made for more than ten years, and a large amount of work done in this period is probably wasted, since we do not dare to bring the results obtained into any relation with soil problems.

I have emphasized this problem of the "soil as a culture medium" for two reasons. The one is that our laboratory is dealing with this special problem, the other is the urgent need of this work. How can we expect to make progress in soil bacteriology if we neglect factors of the most vital importance for microbial development?

Soil is such a complex mass of organic and inorganic, soluble and insoluble compounds, containing so many different organisms that we cannot possibly oversee all the changes taking place at once. It will be absolutely necessary to reduce the number of unknown factors in soil. It will become necessary to study the development of pure cultures in soil before we can think of dealing with the natural microbial flora and fauna of soils. It will require a large amount of careful and possibly discouraging work to study the peculiarities of soil as a culture medium, but it offers a chance for fundamental, and, I dare say, classical work in soil bacteriology.

Processes other than aeration will probably play a rôle in the microbial development in soil, since it is believed by some chemists that even chemical reactions are different in soil from solutions.

Cameron stated last year (Journal of Physical Chemistry, Vol. 14, p. 402 (1910) . . . . . ."We should expect that many reactions would take place quite differently in the soil from the way they would in a beaker or flask. This fact has been generally overlooked or ignored and is probably the explanation of many of the apparently anomalous results hitherto reported in chemical investigations of soils. Enough is known to justify the statement that the chemistry of the soil need not be and probably is not, the chemistry of the beaker."

And still, another factor must be considered as possibly influencing microbial development in natural soils. The publications of the Bureau of Soils have demonstrated that there are organic compounds in soil which retard plant growth. The same or similar compounds may retard bacterial growth. Investigations have never been made along these lines, but the possibility must be considered.

One other problem must be mentioned here which has been considered so little as yet that we cannot even say whether or not it is important to soil fertility. It is the relation of microörganisms to the physical structure of soils. The formation or destruction of humus will certainly influence the physical qualities of soils. But even aside from that, soil is changed physically by microörganisms. A root, a leaf, a piece of straw in soil will decay and the space previously occupied by organic matter is later an air space, a channel for ventilation. The oxidation of soluble ferrous salts to insoluble ferric salts is apt to change the structure of soils, and so does the solution of insoluble phosphates and carbonates by acids formed by microörganisms. There must he considered further the mycelial growth of molds, and possibly the formation of slime by bacteria. The experiences with sand filters indicate the probability of such influences.

These are some of the great problems which seem to our laboratory the must urgent problems of the soil bacteriology of today. There are many other problems waiting for solution, and they may seem more important to other laboratories.

The solution of such problems depends largely upon the development of the technique. The interest of the microbiologist concentrates in the products of microbial metabolism, and the success of determining accurately the character and quantity of the products of any decomposition depends upon the accuracy of the chemical analysis. The difficulty of analyzing the many compounds in soil has already been pointed out by the chemist's paper. Any improvement in the accuracy of chemical analysis will be of benefit to the bacteriologist. The new method of determining very small amounts of nitrogen which has been worked out in recent years by Mitscherlich will no doubt open a new field to soil bacteriology. The method of determining amino-nitrogen in soils which has been worked out by Mr. Robinson, of the chemical department of our experiment station, will be of great, value in the bacteriological studies of the decomposition of humus and peat.

But it is not only the *chemical* technique that limits the study of soil bacteriology. The main difficulty lies in the nature of the material we work with, namely the living organisms. While the chemist and physicist have a constant matter with which to work, the bacteriologist deals with organisms that may multiply, or die, or lie dormant, that are influenced by slight changes of temperature, of moisture, of aeration. The variation of organisms under apparently equal conditions causes frequently a greater discrepancy of results than the probable error of chemical analysis. How difficult it is to avoid mistakes) is seen in the different growth in soil and solution which was not considered at all important for more than ten years. The problems of soil bacteriology are different from those of dairy bacteriology, and the ' methods used in the latter cannot be applied directly to the former.

Soil problems require, above all, a careful consideration of soils as a medium for microbial development. The field is too new to permit bold, haphazard experiments. The conquest of such new land often necessitates a retreat on the whole line unless each step is guarded by reliable troops. This had not been the case in soil bacteriology, and the retreat was a hard lesson. Slowly, step by step, we must investigate the character of soils in relation to microbial growth, we must study the mutual relations of the various organisms, and since all bacteriological work is based upon the physiology of microörganisms, great efforts should be made to amplify our knowledge of the physiology of these smallest organisms. The solution of soil problems requires a strictly scientific study of all factors involved. Without such scientific basis, it may be possible after many mistakes to establish a few isolated facts but never a science of soil bacteriology.

East Lansing, Mich., April, 1911.

SOIL AND SOIL PROBLEMS FROM STANDPOINT OF BOTANIST.

W. H. BROWN.

The soil problem from the standpoint of the Botanist or Plant Physiologist may naturally be divided into two parts:

1. The influence of the soil on the plant.
2. The influence of the plant on the soil.

In dealing with the first part of this problem, the methods used by the Plant Physiologist have usually not differed greatly from those employed by the Soil Physicist or Chemist, since they have usually consisted in an attempt to correllate the chemical or physical factors of the soil with either the total or dry weight of the plant produced. This has been largely the result of the fact that plant physiology is a comparatively new science and that certain general relations had to be established before the underlying physiological problems could be attacked. While from a physiological standpoint, such methods could hardly more than scratch the surface they have nevertheless yielded valuable results. For example it has been found that certain elements are necessary for plant life and that the plant can obtain these from certain chemicals and not from others, that some combinations of chemicals are favorable to growth, that a certain texture or water content of the soil is necessary for some plants and that these conditions vary for different species. In much of the work along this line, however, the mistake has been made of dealing with a complex of factors rather than with individual ones, with the result that the experiments could not be repeated or fundamental conclusions, which would serve as a basis for future work, derived from them. For example, the addition of certain things such as fertilizers or organic matter to the soil has often been treated as an experiment with a single factor even though the things added have been complex and have changed the physical and chemical properties of the soil and influenced the microörganisms in it. Even when individual factors have been dealt with, the relation of these to others has frequently been so complex that some factors have either been ignored or overlooked, with the result that later work has proved the first conclusions either inadequate or erroneous. A good example of this is afforded by the non-available water content of the soil which is the water remaining in the soil after the plant has withered and died because it could not obtain sufficient to supply that lost by evaporation, and to maintain life. The amount of this non-available water has been found to vary with different soils and plants and so without taking into consideration the atmospheric conditions it has generally been stated that it is constant for a given soil and plant. Experiments carried on in Arizona have however, shown that similar plants of *Vicia faba* growing in the same soil, would wilt when the soil contained anywhere from 8 to 35% of water, depending upon the amount of evaporation. As will be pointed out later changes in the internal conditions of the plants also affect the amount of non-available water. While it is thus evident that much of the work that has been done will have to be repeated under more exact experimental control, the realization of the complexity of the problems will do much to remove the present unsatisfactory condition.

But what, after all, is the most unsatisfactory thing from the standpoint of the physiologist is the small amount of work that has been done on the processes of the plant itself. Little is known about the form in which substances enter the plant, and still less about the relation of conditions in the soil to the internal conditions of the plant and of these internal conditions to growth. While these problems are complex, they are by no means hopeless and should be of tremendous importance from both a scientific and practical standpoint. It may not therefore, be out of place here to discuss some of the possibilities.

Since chemical reactions take place more rapidly in a dilute than in a concentrated solution, we would expect growth to be more rapid when the solution in the cell is dilute than when it is concentrated, provided, of course, that the necessary elements are present in sufficient amount. If a submerged plant such as Elodea, is placed in distilled water or in a very dilute solution of nutrient salts where the tendency would be for the salts to diffuse from the plants to the water and thus weaken the solution in the cells, the plant will grow several times more rapidly during the first three days than if it were in ordinary pond water. Rapid growth does not, however, necessarily mean good growth, and in this case, the plant usually dies about the fifth day. Plants growing under arid conditions usually have an extremely slow rate of growth and the concentration of their juices is higher than that of plants growing in moist localities. Likewise when plants that have been growing under moist conditions are subjected to drought, their juices become concentrated and growth is less rapid or may cease altogether. From the above observations, it would seem probable that the degree of concentration of the juices of a plant may markedly affect the rate of growth. The water content of many plants may be reduced 50 per cent, without causing signs of wilting, by decreasing the amount of water in the soil. In this case, there must be a great increase in the concentration of the solution in the plant cells and an increase in the osmotic pressure. This is followed by a great decrease in the amount of water given off by the transpiration of the plant. Plants thus give off and take up less water when growing in a dry soil than when growing in a moist one. The fact that the amount of water in a plant decreases as the soil becomes drier should find a ready application in agriculture in regions where irrigation is practiced, for if the optimum water content of the leaves were once determined, it would be easy to tell when the per cent of water fell below this. This would indicate that it was time to irrigate, and remove all uncertainty. In all probability growing a plant in a concentrated solution would have the same effect in increasing the concentration of the plant juices as growing it in a dry soil, for the amount of

salts taken in a plant is not regulated by the amount of water that passes through it but by the relation between the concentration outside and inside the plant, since the salts move by diffusion and this may be independent of the movement of the water.

It is well known that certain plants will not grow in soils in which the water contains a large amount of dissolved salts. When we ask for an explanation of this, we are confronted by difficulties which can only be solved by a careful study of conditions within the plant. The harmful effect might be due to an increased concentration of the juices of a plant; or possibly changes in permeability; or to an actual harmful effect on the cytoplasm; or to an interference with the working of an enzyme or some other process. The presence of certain salts in solution may either accelerate or greatly retard the action of enzymes and it is very probable that in plants as in animals, the presence of certain salts is useful in accelerating or retarding various processes. Unfortunately, however, we know entirely too little about the condition of substances within the plant. A good example of the importance of changes in the relation between conditions in the soil and in the plant would seem to be afforded by the non-available water content of the soil. During the day, the leaves of plants are manufacturing sugars which increase the concentration and osmotic pressure of the solution in the cells. At night these sugars are used or removed and the concentration and osmotic pressure again decreases. Since water is probably drawn into the cells by osmosis, we would naturally expect that in the middle of a bright day when the osmotic pressure is high, the water would be drawn into and held in the cells of the leaf with greater force than during the night or early morning, or on a dark day, and that therefore, the amount of water in the soil which is not available to the plant would vary with the time of day and kind of day. This has proved to be the case to such an extent that these factors will have to be taken into consideration in all accurate determinations of non-available soil moisture.

Enough has probably been said to point out something of the importance of studying the conditions within the plant in their relations to soil problems. A thorough understanding of this relation would certainly furnish a satisfactory way of handling many practical questions.

The influence of the plant on the soil, like that of the soil to the plant would appear to be a fruitful subject for investigation rather than a field in which a great deal has been accomplished. Substances which are toxic to plants may be formed in soils as the result of the growth of plants, but whether these are usually excretions from the plant or the result of bacterial decomposition of tissues thrown off from the plant, is uncertain. Many plants particularly fungi and insectivorous ones are known to secrete enzymes and other substances so it is entirely possible that plant excretions may play an important role in changing the chemicals of the soil. The growth of roots appears to be accomplished in some cases by a dissolving of mineral substances, but how much of this is due to things outside the plant, such as acids produced by the decay of tissues is also uncertain. The meaning of the oxidizing and reducing power of roots is likewise little understood.

In conclusion the soil problems from the standpoint of the botanist would appear to me to be one on which comparatively little has been accomplished but which offers tremendous possibilities.

Michigan Agricultural College, East Lansing, Mich., April, 1911.

THE THEORY AND PRACTICE OF SOIL MANAGEMENT.

FRANK K. CAMERON.

The watchword of modern industrial efforts is efficiency. Efficiency implies control; control of materials and control of methods. Control in turn implies knowledge and understanding of materials and methods.

We are met here today in symposium to study the problem of efficiency in soil management. It is meet that this should be so, for this is the *place* where labored for many years a Nestor among soil investigators; the scientific public and especially those more immediately concerned with the soil and soil problems have long looked with admiration and for inspiration to the labors of the late Professor Kedzie. The *time* is propitious, for we are now entering an era of scientific discussion following one marred by acrimonies because a theory has been brought into question—a theory which for three-quarters of a century and upwards dominated the thoughts of soil investigators practically to the exclusion of all others. Useful as was this theory and satisfactory for its time, it is now giving way to, or perhaps it would be better to say, being modified by, increasing knowledge and new points of view. The word *symposium* is, in its derivation, suggestive of drinking together, a simile quite apt to this occasion, for the program we have followed today shows that to attain a comprehensive purview of the soil, we must now draw from the founts of many sciences. The work of the physicists, the chemists, the biologists and the geologists is obviously necessary to a knowledge and understanding of soils. Looking further into the larger aspects of the case and the relation of the soil to human progress and welfare, it seems evident that there is no branch of knowledge but what lends itself to or finds itself called upon in soil investigations.

Finally, the *soil* itself is a subject which is not surpassed in interest by any other. It presents to the scientist many complexities, sometimes baffling, but ever interesting, always suggestive of new lines of thought and of original experimentation. To the practical layman it offers, in soil management, a subject rapidly becoming a highly developed art, passing from the avocation of an artisan to the profession of a highly trained expert. Upon the soil more than upon any one thing depends the material prosperity and happiness of the race, and equally important is its part in determining the development of

the spirituality of the race. However facinating the soil may be to the scientific man, and however strong the justification in studying it for its own sake or simply to add to the sum total of human knowledge, and however interesting in its relations to the æsthetic and emotional development of the race—and these views of the subject are well worth considering in an institution of learning—today we are to think of it from another point of view. The labors; of our colleagues, who are working upon the soil as chemists, physicists, biologists, geologists, etc., are justified by the instrumentation they place in our hands for the management, i. e., control and efficiency of the soil as a source of food.

The great fundamental problem of agriculture is crop production. Efficiency in crop production is not always recognized, nor even what efficiency means. There is an important distinction between quality of crop and quantity, the attainment of the optimum in either direction being not always compatible one with the other. Frequently if not generally these ends are antagonistic, and it is a question of nice judgment so to adjust the several factors determining crop production as to obtain the best compromise between quantity and quality. For such a judgment, and such an adjustment, there is requisite a knowledge of the several factors, their several functions and their relations to one another. Crop production is the resultant of many factors. It depends upon the biological characteristics of the plant, upon the viability and germinating power of the seed, the species and varietal differences. It depends upon climate especially, the amount and distribution of rainfall and of sunlight, and upon temperature variations. It depends upon the soil, including the composition and character of the mineral components and of the organic substances, including the yet mysterious complex, humus. It depends upon the physical properties of the soil, its textural characteristics, its absorptive powers and water movements; upon the biological properties of the soil, including bacteria, molds, enzymes. With these natural factors may be included others of which at present no opinion can be ventured other than the possibility of their existence. To these in the case of cultivated crops, must be added three artificial factors which comprise nearly all that man has yet devised for the control of soil and crop, namely, tillage methods, rotations, and fertilizers. The use of wind brakes, shades, glass houses, etherization, spraying, etc., are all very special practices for special cases, and need not be considered in a general discussion, as they have no wide application to field crops.

Consideration of the factors determining crop production and the experimental investigations of them, brings a realization that the resultant of all these variables is complex. Not only are the factors numerous but they are interdependent, and no one of them can be changed without producing corresponding changes in all the others. These are points of great importance, for up to the very recent past it has been assumed that crop production is a simple matter, dependent primarily upon the amount of plant food available, although it was recognized that the weather sometimes interfered and that some tillage was necessary to the production of any crop at all.

Let us confine ourselves for the present to a consideration of the soil factors. The soil is the resting place for the products of practically all the activities taking place on the face of the earth. Agriculturally we may confine the term soil to that portion of the solid crust of the earth which is or can be adapted to the growth of crop plants, and in it are to be found results of these various activities, natural and artificial. The soil contains a vast array of mineral particles. It is true that sometimes certain minerals or groups of minerals will predominate and give convincing evidence of the rock origin of the soil. Sometimes, however, the soil shows no obvious relation to any particular rock. But investigations to which attention only can be called at this time, have made clear that practically every soil contains some at least of every kind of rock forming mineral. To these are added the products of organized life and the degradation and decomposition products resulting from them. Mineralogical investigations showing the large numbers and variety of minerals present in every soil are equalled in importance by some recent chemical investigations which show an amazing variety of elements. In each of a series of soils from different sections of the United States, east of the Mississippi, there has been found in detectable and generally in estimable quantities nearly every known element. And in the organic residues of ordinary soils which have been under cultivation, there have now been isolated and identified some twenty definite chemical individuals, of at least eight different types.

Water and winds are constantly transporting soil material from place to place, so that in all cases the soil is far more heterogeneous than any rock. Aside from the heterogeneity of soils, the results of these activities of water and winds are easily recognized. Throughout the humid areas of the world it is a general rule that the surface soil is lighter in texture than the subsoil, though the former is derived from the latter, the smaller particles being more easily removable. In arid regions this rule will not apply, for special conditions determine soil formation in each and every area. Within any given area of the soil itself we recognize that the particles must be moving continually. The sinking of heavy objects into the soil is an evidence of this. We know that earth worms, burrowing animals and like transporting agencies are of great importance, but more than these is the importance of the alternate wetting and drying of the soils incident to weather changes, which wetting and drying is accompanied by expansions and shrinkages which do not exactly balance one another and which must in consequence be accompanied by movements of the individual particles of the soil, and by a considerable mixing and transporting of these particles among one another. From the very nature of the case we know that living organisms within the soil must be moving, and all the biological factors are continually in process of change.

The water falling upon the earth makes possible the use of the material as a medium for plant growth by bringing in solution to the absorptive tissues of the roots, the mineral elements which we all now recognize as essential to the growth of plant and animal. In falling as rain, a portion of this water fails to enter the earth by remaining in the air as vapor. Another portion runs off from the surface, while the remainder enters the soil and percolates through it, mainly as the result of gravitational forces and through the larger soil openings. Some of this water goes into the soil, seeps through and appears at the surface in the form of springs and wells and passes off into the drainage of the area. This water, dependent upon the character of the soil, the length of its passage and other obvious factors, dissolves from the soil some of the mineral matter, and so we find all our creeks and rivers diluted soil solutions of varying composition and concentration. As the surface of the soil dries there is developed there a capillary drag or pull, and some of the water which has entered the soil reascends to the surface, generally more slowly than it penetrated into it, passing in this case over the surface of the soil grains as films, being long in contact with them, so that there is continually being brought to the surface of our soils a solution containing the mineral elements, including those necessary to plant growth. So far as investigation can determine the matter at present, it appears that the concentration of this solution does not vary very much in composition with respect to those mineral constituents which are recognized as of importance to plant growth at least within a given area or in areas under similar climatic conditions, and the concentration of the solution, except in special cases, is much higher than that of the seepage water, being on the average in the United States probably ten times as high.

Calculations based on observations of the rainfall and runoff of our principal areas, as well as some direct experimentation, show that under normal conditions such as those obtaining in the humid areas of the United States, upwards of two-thirds of the rainfall enters the soil, penetrates to the subsoil, and returns to the surface, carrying with it dissolved material which is available for plants. A consideration of this line of inquiry leads to the conviction that practically all the mineral plant food utilized by growing crops is being brought to them from the subsoil where the roots do not actually penetrate. There is much evidence in favor of this view, though time will not permit me to lay it before you today. But it is clear that we must recognize not only the interdependence of soil factors as well as other factors in crop production, but we must recognize furthermore that every factor in the soil affecting crop production is continually changing, and that the problem is essentially a dynamic one, not susceptible to the application of static considerations, which have so long been popular and in some quarters are still so. The analogy of the soil to a bank from which deposits of plant food are being drawn is essentially false. Rather is the soil like to a complicated machine with many parts, each running according to its own specific purpose, but the whole to the general purpose of turning out a definite finished product; and this product in quality and in quantity is determined by the way each separate operation is performed, as well as by the character of raw material furnished. Like such a machine the soil if not used or if misused, "rusts," but properly used it increases in efficiency. Analogies are, however, very dangerous as arguments, and I would not have you fail to recognize that in some essential features the soil no more resembles such a mechanical device than it does a bank.

With these soil factors admitted, another conviction comes to mind. A simple substance has but relatively few characteristics. One amoeba is like another, one drop of water is not essentially different from another. As complexity increases, so does differentiation, and as we pass to the highest complex of which we have any knowledge, the civilized human being, the differences between one man and another are quite as prominent as the similarities. Two engines built from the same shops, from the same patterns and in the hands of the same engineer differ in performance as a rule. The soil is extremely complex, consequently no two soils are alike, and the more they are studied the more it becomes apparent that the differences not only between soil types but between different fields of the same soil are fully as important as are the similarities. No two fields can be expected to have the same crop producing power or the same adaptability to crops or rotations of crops, or the same responsiveness to a given tillage method or fertilizer treatment. In other words, soils are highly individuated, a fact not generally recognized, but of the first importance to an intelligent and rational management.

Let us turn now to a consideration of the instruments or methods of soil management. As stated before, these may be classified under three general heads, tillage, crop rotations, and fertilizers. The essential fundamental facts which it is important to bear in mind here is that no one of these methods can be expected to take the place of the others, although they do all affect the same natural factors and consequently are thus mutually interdependent. Tillage obviously affects the physical properties of the soil, but it affects also the chemistry of the soil, for the altered movements of water, of carbon dioxide content of air, and possibly other relations in the soil affect profoundly the inorganic and organic relations. No less profoundly are the bacterial flora and other biological features affected. But fertilizers, as recent investigations are making obvious, produce as profound changes in the physical properties of a soil as do tillage operations, and that they affect the chemistry and biology of the soil no one can question. Nevertheless in their net results we must consider tillage and fertilizers as differing not only in intensity or amount, but essentially in kind. Two great errors with their attendant lessons are before the American public at the present time. In the South Atlantic States tillage has been, speaking generally, poor and unsatisfactory, rotations

uncommon, and the dependence is upon fertilizers under the mistaken idea that plant foods alone are what the soils need. In the trans-Mississippi areas generally rotations are again neglected, fertilizers are seldom used because of the supposed superabundance of plant foods or "fertility," and the dependence is alone or almost entirely on tillage.

Time will not permit of any great amplifications of these illustrations, but abundant evidence is coming to hand that both procedures are at fault. The introduction of diversified methods of farming and better tillage in the South has established beyond question that the soils of that region have a value for crop production immeasurably higher than the popular notion. The increasing demands for the lands of the western States has directed attention to their yields. There is a popular impression that these yields are falling off—a doubtful opinion in view of such official records as are available, but it is certain that they must increase to justify the continuance of their relatively high money value, and if they are to meet the growing demands of an increasing population. The lessons which these considerations teach are sufficiently clear. Modifications of tillage methods, introduction of new fertilizer materials, adaptation of rotations to special soil peculiarities, climatic environment or market conditions will undoubtedly be worked out for each locality, but essentially the principles are the same.

It is an interesting fact worthy of the most serious consideration of both the scientific investigator and the practical layman that we have no definite idea as to the limit, of productivity of which soils are capable. Under greenhouse and laboratory conditions yields; can be obtained enormously higher than are actually gotten in the field. This is contrary to the general rule in industrial operations. It is well established that the factory practice is more efficient than the laboratory. For example, the operation of crystallizing cane sugar, practically pure, in the mill is a commonplace of the industry, but can not be accomplished on a laboratory scale. I have recently been assured by one of the most skill-fill metallurgists in this country that certain methods which he had studied for years in the laboratory only to find that they "would not work" although theoretically sound, were found to be very easy of accomplishment and remarkably efficient when he finally had the courage to try them in actual smelter runs. These facts indicate that in soil management, actual performance is yet very far behind what we have a right to expect. But more than that, the yields obtained in artificial cultures, so far from showing what the maximum possibilities are, should rather be regarded as indicating the inferior limit allowable in actual practice. This view may seem revolutionary to some, and it would be, if we are to look forward to an indefinite continuance of farming by present methods. But actual examples of sustained yields of high quantity in such special crops as truck, tobacco, etc., show that the possibilities have not yet been realized and that with the development of the future, present results will look woefully inadequate. It is but a few generations since the physician was regarded as a sort of lower servant who practiced with approbation crudities that today would land him in the madhouse; today he performs as ordinary incidents of the day's routine operations that were not impossible but undreamed of a half century ago, and his position in the community is not surpassed in the homage and respect it commands. The profession of engineering of today has developed from equally humble origin and other examples will occur to every one. It is not so long since the farmer was a serf, but there are many reasons to believe that soil management is developing in a similar way to medicine, law, engineering, etc., as witnessed by the existence of such institutions as the one in whose halls we are now met, and by the fact that it commands the gathering in conclave of trained investigators in such diverse inquiries as have been brought before us today. The view is not revolutionary, but will, I am sure, appeal to you as entirely logical, and that if the technical investigators do well their part, the farmer of the not distant future will not be behind the smelter superintendent or the up-to-date manager of the factory.

Soil management is for the production of the crop and the crop is made up of plants. The modern crop plant is already a highly artificialized entity. It is not reasonable to expect the co-ed graduate of Michigan's higher seats of learning, however satisfactory and beyond criticisms she may be in her native environment, to make a satisfactory wife to the roving Hottentot or the nomadic Esquimau. Just as reasonable is it to expect a highly bred strain of wheat to fare well on a soil and under management that would discourage a jimson weed. It is not a question of food; your Esquimau eats more than your college athlete, and gets it when his civilized compeer with all his modern equipment would starve, yet the Esquimau is inferior in production either of physical or mental output. Our soil management must be developed with this thought constantly in mind that the organisms for whose production the management is practiced is highly artificialized and cannot maintain itself successfully without continual supervision and aid. It is not surprising therefore that the soil must be artificialized to some extent for the best production of the artificialized plants. The thoroughly tilled and freshly fertilized field is better suited to crop production than a virgin prairie, but also more sensitive to mistakes in management or judgment. Far too often is the soil blamed for the shortcomings or errors of the farmer. By slight changes of condition in the laboratories we can induce a seedling plant to grow long or short roots as compared with the tops; but does any one yet make use of this knowledge in growing a field of wheat? Mineral nutrients are essential to metabolism in all organisms, but is it not foolish to pin our faith on this alone, when for instance it has been shown that the ragweed following a wheat crop takes out of the soil more of the mineral nutrients than does the wheat crop. Rather is it not more reasonable to infer that the inability to produce a satisfactory repetition of the wheat crop is due to the fact that so artificialized a plant as the wheat, in which habits have been bred into

characteristics, can thrive only under a special combination of soil, climate and seasonal factors which can not be realized in the soil from which the crop has just been removed.

We are led here to consider another important generalization which has not received the consideration it should. It is a characteristic of all activities, physical, chemical or biological, that as the activity proceeds in any definite direction, products of the activities accumulate and slow up the action, ultimately stopping it if the products are not removed. This generality holds for waste products or so-called by-products as well as for the main ones. The factory cannot continue unless byproducts are removed. Manure must sometime be removed from the barnyard. Every housewife knows that the kitchen cannot be managed without removal of the garbage. In chemistry we have the well known law of mass action which in different forms has its application in physics and biology. The bacteria or the yeast cannot continue to live and thrive when the medium in which it exists reaches a certain concentration with respect to its reaction products, a familiar example being the fermentation of sugar to alcohol. But some other ferment can, however, live and thrive in the medium, as the butyric acid ferment. Rats are said to be able to live in an environment which man or some other higher animal has fouled beyond the point of habitability.

So with our crop plants. Because of their higher artificiality they are the more prone to unfit their environment for continued production, unless the environment be artificially assisted by suitable management, and to this end we must investigate the causes, whether toxic organic substances, disturbed bacterial associations, or whatever they may prove to be in any particular case. The principle to which the president of the American Chemical Society called attention recently as a universal law, finds ready application here. The ragweed requiring as much "food" and water as the wheat will grow in the soil which cannot be replanted to the latter, but (in certain regions which have been under my own observation at least) the ragweed itself gives place the following spring to blue grass.

What then is the theory of soil management? In the sense of a simple, formal statement, there is no theory. At the best such statements can be but a part of the whole truth which is the basis of soil management. It is never true that the crop growth is or would be determined by a minimum content of any one mineral element or by a maximum content of some organic substance, or by a given ratio of protozoa to bacteria or ratio of water content to air space. Any one of these may, in a particular case, be a factor of even predominating influence, but always the crop is determined by a large number of factors, and it is not rational to describe any one of these various contributing factors in crop production as a theory of fertility or a theory of soil management.

The increase of knowledge concerning the chemical processes taking place in soils, the function of water as a great reactive agent in preparing the mineral constituents for the easy assimilation of plants, the translocation of such materials from subsoil to surface soil, the part that other mineral constituents than those recognized as plant foods may and probably do play in affecting quantity and quality of product, the chemical and physical effects of organic substances which are now being separated and recognized by definite scientific criteria, the biological activities, the various types of bacteria or their antagonists, the protozoa, all this information in each and every case conies back practically to the question of soil management. How they are controlled by tillage, by rotation, by fertilizers; how a just balance between these factors is to be sought for the production of a crop of given quality or given mass or volume. Such an adjustment must always be a matter of judgment. Therefore soil management is an art, dependent upon investigations of a large group of sciences, which we can call for convenience, *agricultural science*.

In the practice of this art the labors will be much lightened if the expert has an intelligent clientele. No effort should be spared to bring the modern concept of the soil and its relation to crop production to every farmer in the community. It will be found more interesting and more reasonable than the stereotyped views which have preceded it and so long maintained their sway. And with an assimilation of these ideas will come a mutual understanding between the farmer and the expert. With a recognition of the fact that the soil is an individual and must be treated as such will come an effort on the part of the farmer to adjust his management to it, and enable him to put before the expert a clearer picture and to formulate a cleaner question, when difficulties are encountered. Nothing is more trying to the soil investigator than to be sent a sample of soil and to be asked to analyze it and tell what fertilizer it needs and what crops will grow on it. But yet the question is a fair one under past conditions and the expert has no one to blame but himself for the fact that the layman does not know that no stereotyped method of examination, physical, chemical, or biological can possibly tell what a dynamic system will do under a specific but dynamic environment.

Quite recently there has been a great public awakening in this country, a prominent feature of which is a greater appreciation of the importance of the nation's soils. The time is ripe for the minds of the people are in a receptive mood for the newer knowledge which such gatherings as this are making available. Surely the farmer will take a keener and more intelligent interest in his soil when you show him that instead of being a dead, inert mass of rock and plant debris, it is scarcely less active than his stock; that changes are going on in it all the time, changes which are as susceptible to control as the feeding and working of his stock. That each field is an individual which he must continually study, coax, repress or force as he would his growing herd. The true soil

management absolutely precludes monotony, for never twice does the same field, even with the same crop, present just the same problems, and no stereotyped practice can bring the best results any more than a stereotyped "analysis" will enable you to advise him.

The State of Michigan is to be congratulated in that the Academy of Science recognizes the importance and the character of soil investigations by formulating the comprehensive program of today. The State is to be congratulated that the State Agricultural College and Experiment Station have inaugurated the comprehensive and coordinated' investigations which have made possible this program. For alone, neither the chemist; the physicist or mineralogist; nor the biologist can longer hope to advance in soil work. Each must have the continued assistance of the others. No longer can the Michigan farmer continue with success the methods of his father or grandfather. He must develop a judgment that will enable him to handle each particular field according to its own individual merits for definite crops or rotations. To this end he can now command invaluable assistance from the soil surveys; from the office of the experiment stations; and from the professors in the State Agricultural College. Above all, from his own observations and deductions can he get direction for the future. But to get intelligent counsel from reading, observation, or expert, the farmer must know the nature of his problem and the character of the principal processes taking place therein.

To sum up, the principal points that I would like to emphasize are: That soils are complex, but that they are susceptible to management and the development of high efficiency; that the methods for doing this are fairly well known; that in its major outlines the theoretical basis of soil management is fairly simple, and that its practice is rapidly becoming a highly developed art which needs for its best application a comprehensive coordination of the labors of the physicist, chemist, biologist, and other investigators, and a clearer understanding between the layman and the expert as to how they may be mutually helpful.

Washington, D. C., April, 1911.

PROGRESS OF THE GEOLOGICAL AND BIOLOGICAL SURVEY OF MICHIGAN.

R. C. ALLEN, DIRECTOR, AND A. G. RUTHVEN, CHIEF FIELD NATURALIST.

Geology and Topography by R. C. Allen.

Members and friends of the Michigan Academy of Science:

In accordance with the invitation of the Academy so courteously extended to us last year I have the pleasure to transmit to you a report of the progress of the Michigan Geological and Biological Survey. The work of the department of Geological and Biological Survey is conducted under three divisions, each of which is provided with a separate appropriation. These divisions are:

1. The division of Geology established by the law of 1869, providing for a continuing appropriation of $8,000 annually.

2. The division of Topography which is conducted under special appropriation from the legislature, the appropriation for the fiscal years 1909-1910 and 1910-1911 being $2,000 per annum.

3. The division of Biology established by law of 1905 which is also conducted under special appropriation from: the legislature, the appropriation for the fiscal years 1909-1910 and 1910-1911 being $1,000 per annum.

The law of 1869 as amended provides that a survey shall be conducted under an ex-officio board, which shall be composed of the Governor, Superintendent of Public Instruction, and the President of the State Board of Education, who shall constitute a Board of Geological Survey. This Board is directed to "appoint and commission a suitable person, possessed of the requisite knowledge of the science of geology, who shall be Director of the Geological Survey hereby instituted." The Director has, by custom, since the passage of this law, been called the State Geologist. The act of 1905 establishing a biological survey reads in part, "that the Board of Geological Survey is Hereby authorized and required to make, under the direction of the State Geologist appointed by them, a thorough biological survey of the state." It appears then that the State Geologist referred to in the law of 1905 and the Director of the Geological Survey, the position established by law of 1869, are one and the same person, so we have, therefore, in this state as constituted at present, a Geological and Biological Survey under the direction of a Board of Geological Survey and prosecuted under supervision of a Director, whose appointment and commission is provided for in the law of 1869 as amended and who is referred to in the law of 1905, establishing a biological survey, as a State Geologist.

At a meeting of the Board of Scientific Advisers in April, 1910, it was recommended, and approved by the

Director and the Board of Geological Survey, that the organization be called the Michigan Geological and Biological Survey.

The division of Biology is conducted under the direct charge of a Chief Field Naturalist, who is appointed by the Director, with the approval of the Board of Geological Survey. Dr. Ruthven reported to you at the last meeting the progress of the biological survey and will report to you at this meeting the progress of the biological survey during the past year.

The report upon the progress of the geological and topographic work which follow covers the period from my appointment, September 1, 1909, to date.

GEOLOGY.

Active field work has been prosecuted in the Northern Peninsula in both the copper bearing and iron bearing districts, and in parts of the Southern Peninsula.

Northern Peninsula.

Copper Country: Report on the Geology of the Keweenawan or Copper Bearing Rocks.

My predecessor, Dr. A. C. Lane, had, during his long period of services as State Geologist, become especially conversant with the geology of the Keweenawan or copper bearing rocks and at the time his resignation became effective had partially completed a monograph on the Keweenawan Series of Michigan designed to be an exhaustive treatise embodying all information of scientific and economic importance on the subjects treated. Dr. Lane was therefore requested to complete his work as soon as practicable and money was appropriated for the purpose from our funds. The Survey has co-operated with Dr. Lane in bringing this work to successful completion. Mr. Karl S. Meuche was employed as assistant to Dr. Lane. The manuscript of this report is now complete and ready for publication.

Iron Region: Report on the Geology of the Iron River District.

Prior to his appointment as State Geologist the writer had been engaged by the Board of Geological Survey to make a survey and report upon the geology of the Iron River district. Field work was prosecuted during the summer of 1909 and also during a part of the summer of 1910, which was followed by a report, published and distributed in February, 1911.

Geologic Mapping West of the Iron River District.

During the summer of 19.10 a party of from 4 to 7 men were engaged in geologic mapping of 11 townships, viz.: T. 45 N., R. 35 W., Tps. 42, 43, 44 and 45, R. 36 W., Tps. 42, 43, 44 and 45, R, 37 W., and Tps. 43 and 44, R. 38 W., tying west of the Iron River district. Blue prints of the field plats may be obtained at cost on, application. The completion of the work on the Iron River district and the mapping of these townships forms a very good beginning on the general plan of mapping as rapidly as possible the unmapped Huronian areas of the Northern Peninsula. A reward of careful magnetic work, which was carried on simultaneously with the geologic mapping, was reaped in picking up a magnetic belt in Section 16, T. 43 N., R. 37 W., and carrying it thence westward over a deeply drift-covered area where there are no rock exposures, to the state boundary in Section 16, T. 43 N., R. 38 W., a distance of about 6 miles. This magnetic belt is doubtless underlain by iron bearing rocks which in the future will be explored by drilling, with the probable result that bodies of iron ore will be discovered and exploited.

A map of the Surface formations and soils of the northern peninsula.

During the past 5 years the survey has been co-operating with the U. S. Geological Survey in the mapping and study of the glacial or surface formations of the Northern Peninsula. The field work was completed under charge of Prof. Frank Leverett during the summer of 1910 and a map on a scale of six miles to the inch is now finished and ready for publication. It will show in appropriate colors and symbols the distribution of the various classes of soils and the features of glacial geology, etc., on an excellent black base. It is planned to issue an edition of 3,000 of this map and a new edition of 3,000 of a similar map of the Southern Peninsula, which was published in the annual report for 1907. These maps will be accompanied by a descriptive text by Prof. Leverett, written in simple style in order that it may be fully comprehended by the average Michigan farmer. We have now on file many advance applications for this work. It will aid very materially in the agricultural development of the unpopulated areas of the Northern Peninsula and the northern half of the Southern Peninsula. The publication of these maps and descriptive text is timely, in view of the-awakened interest in agricultural development, especially in many parts of the Northern Peninsula.

Southern Peninsula.

Report on the Monroe Formation of Southern Michigan and Adjoining Regions.

The work of Professors Grabau and Sherzer which has been in progress for several years has been completed and issued as Publication 2, Geological Series 1. This is a monographic report of about 250 pages, not including about 100 pages of plates and descriptions of fauna and flora. The execution of this work does credit to the ability of the authors and the painstaking care with which the work has been done. The high praise accorded it by the lay and scientific public is a source of much gratification to the Survey.

Report on the Geology of Arenac County.

The text of a report on Arenac county, by Prof. W. M. Gregory, has been completed and is ready for publication. This report is characterized by the same thoroughness of treatment which marks the volumes already published on Monroe, Huron, Sanilac, Bay and Tuscola counties.

Report on the Geology of Wayne County.

A report on the geology of Wayne county is in the course of preparation by Prof. W. H. Sherzer. This work should be ready for the press before July, 1911. We have had many requests for this work in advance of its publication. It will treat in a manner easily comprehended by the reader of average intelligence of the geology, physiography, soils and mineral products of the most populous county of the state.

Report on the Salt Industry.

Field work in the preparation of a report on the salt industry of the state was begun by Mr. C. W. Cook in June, 1910, and continued throughout the summer. Work in preparation of this report is being pushed as rapidly as possible and it is hoped that it will be finished before the end of 1911.

A General Geological Map of the State.

It is planned to issue a general geological map of the state on the black base, scale six miles to the inch, used for the soil map above mentioned, the same to be accompanied by a short descriptive text setting forth in a manner easily comprehended by the non-technical reader the salient features of the general geology, including brief descriptions of the rock formations in the order in which they occur in the geological column, with special reference to features of economic importance. This text is designed only to render the interpretation of the map intelligible to the average reader. There have been received a large number of requests for this map from the schools and educational institutions of the state, citizens, and from many sources outside the state.

Report on Earthquakes in Michigan and the Tilting of the Basins of the Great Lakes.

This report which is ready for press, has been prepared by Prof. Wm. H. Hobbs. It will have special value to school and college libraries and teachers of physiography and geology. The text is beautifully illustrated with numerous pen drawings especially prepared for this report.

Correspondence.

The Survey receives by mail many requests for information on subjects of wide range. These receive the personal attention of the Director and constitute no small draft on his time when not on duty in the field. Some idea of the number and character of the inquiries received may be gained by a glance at the tabulation below, which includes only such inquiries as have been answered by letters. Requests for publications, i. e., reports, maps, etc., are not included in this classification, nor the many requests delivered in person in the office. Some requests are for information on two or more subjects which explains the higher total under classification by subjects. Neither list includes a large number of inquiries which have been received by the Chief Field Naturalist in charge of the biological division.

By calculation it has been ascertained that the number of requests for information thus far in this year exceed those of last year by about 30%.

Classification of Inquiries by Localities from Which They Were Received.

July 1, 1909, to December 14, 1910 (inc).

County.	No. of inquiries.	County.	No. of inquiries.
Alcona	1	Lapeer	1
Allegan	1	Lenawee	3
Alpena	2	Luce	3
Antrim	4	Mackinac	1
Baraga	2	Macomb	3
Barry	1	Manistee	1
Bay	6	Marquette	11
Berrien	3	Mason	8
Branch	1	Mecosta	4
Calhoun	7	Menominee	3
Cass	2	Missaukee	4
Charlevoix	10	Monroe	4
Cheboygan	10	Montmorency	2
Chippewa	6	Muskegon	1
Clare	1	Oakland	3
Clinton	1	Oceana	2
Delta	9	Ontonagon	1
Dickinson	6	Osceola	2
Eaton	2	Oscoda	1
Emmet	3	Ottawa	1
Genesee	8	Presque Isle	11
Gogebic	2	Roscommon	2
Grand Traverse	6	Saginaw	5
Gratiot	6	Sanilac	2
Houghton	14	Schoolcraft	1
Huron	3	Shiawassee	2
Ingham	7	St. Clair	3
Ionia	2	St. Joseph	2
Iosco	2	Tuscola	9
Iron	20	Van Buren	1
Isabella	11	Washtenaw	19
Jackson	4	Wayne	81
Kalamazoo	12	Wexford	1
Kent	24	Outside the State	311
Keweenaw	2	Foreign countries	21
Lake	1		
Total			732

Classification of Inquiries by Subjects.

Subject.	No. of inquiries.	Subject.	No. of inquiries.
Altitudes	1	Maps	174
Biology	52	Marl	8
Bromine	1	Minerals	30
Cement	11	Miscellaneous	100
Clay	4	Oil	15
Coal	26	Peat	51
Copper	12	Salt	18
Drainage	3	Sand	9
Fossils	4	Sandstone	1
Gas	10	Shale	1
Geology, general	110	Soda	1
Gold	4	Soil	26
Granite	2	Stone	5
Gravel	2	Swamps	7
Gypsum	18	Topography	7
Iron	18	Water	17
Lime	3	Wells	7
Limestone	8	Zoological	1
Total			769

Identification of Specimens.

A large number of mineral specimens have been received from prospectors and others with requests for identification and other information concerning them. In many cases the specimens are accompanied by requests for chemical analyses. The Survey does not maintain an analytical laboratory, and even if it did it would probably not be wise to compete with professional analysts in making analyses for private individuals. However, in a great majority of instances the specimens have been fully identified, where necessary by qualitative dry and wet tests, and the information furnished free of charge, thus saving the cost of a chemical analysis.

Mineral Statistics.

The Survey has undertaken the collection of mineral statistics for the year 1910, in co-operation with the U. S. Geological Survey. The statistics include complete totals of quantity and value for all metallic and non-metallic products of the state. As soon as the returns for any product have been received and tabulated the same will be distributed to the press of the state and the complete statistics for all the products will be issued in a separate publication of this department.

It is planned that the collection and publication of complete statistics of mineral production in the state will hereafter be an important and useful feature of the work of this department. A report bearing the statistics of mineral production should be issued on the following plan:

(1) The report should appear promptly as soon as possible after the close of each year; (2) it should give complete statistics for all branches of the mining and allied industries, including metallic and non-metallic products; (3) it should be accompanied by maps and sketches giving location of mines, quarries, etc., and (4) it should contain a general resume for the year of mining conditions in the state, as nearly as possible by districts and products, with special reference to new explorations and the bearing thereon of possible extensions of known mineral producing areas and discovery of new ones.

It is not to be expected that the first report, i. e., for 1910, will embody all of the above features but it is hoped that all of these will be included in subsequent reports.

Change in Form of Publication.

In a meeting of the Board of Scientific Advisers held April 8, 1910, there was considered a plant for improvement in the form and methods in use in the printing and binding of the reports of the Geological and Biological Survey. The plan which was adopted on-the approval of the Board of Geological Survey, and also with the approval of the Board of State Auditors is outlined below:

(1) The plan of binding all of the reports of the Board of Geological Survey issued for one fiscal year under one separate cover shall be discontinued.

(2) The geologic and biologic reports shall be in no case bound together in the same volume.

(3) Reports, either geologic or biologic, dealing with closely related subjects, at the discretion of the Board of State Auditors, may be bound in one volume.

(4) Each separate volume, exclusive of the executive report of the Director, shall form one of a new series, in which the volumes shall be numbered consecutively in the order in which they are published.

(5) The administrative and executive report of the Director shall be issued annually as provided in Section 6, Chapter 55, Compiled Laws of Michigan 1897, and shall constitute, with other publications in a given year, the Annual Report of the Board of Geological Survey.

In addition to the above, the style and quality of the binding, the character of the print and the quality of the text and plate paper have been improved, to the end that now our reports are on a par with the best of those issued by the federal and other state geological surveys. Publications 1, 2 and 3 have already appeared under this new plan of publication.

Publications Issued Since September 1, 1909.

Annual report for 1908. Two volumes.

Volume 1. 402 pages. 3 plates. 6 figures.

Part 1. Administrative report of the State Geologist, A. C. Lane.

Part 2. Geological Section of Michigan for Geologists, Teachers and Drillers, by A. C. Lane and A. E. Seaman.

Part 3. Geology of Tuscola County by C. A. Davis.

Part 4. The Intrusive Rocks of Mt. Bohemia by F. E. Wright. A part of the edition of Parts 2, 3 and 4 of Volume 1 are bound separately in paper covers.

Volume 2. An Ecological Survey of Isle Royale prepared under the direction of Chas. C. Adams. 63 plates and figures.

Annual report for 1909.

Publication 1, Biological Series 1. 95 pages. 17 plates. Containing:

The Crawfishes of Michigan by A. S. Pearse.

The Insect Galls of Michigan by Mel T. Cook.

The Birds of School Girl's Glen by A. D. Tinker.

Preliminary List of the Sites of Aboriginal Remains in Michigan by Harlan I. Smith.

Publication 2, Geological Series 1. 248 pages. 33 plates. 9 figures.

The Monroe Formation of Southern Michigan and Adjoining Regions by A. W. Grabau and W. H. Sherzer.

Annual report for 1910.

Publication 3, Geological Series 2. 160 pages. 17 plates. 18 figures.

The Geology of the Iron River Iron Bearing District of Michigan by R. C. Allen.

Ready for Publication.

The Geology of the Copper Bearing Rocks of Michigan by A. C. Lane. 2 volumes.

The Geology of Arenac County by W. M. Gregory.

A Soil Map of the Upper Peninsula of Michigan. Scale 6 miles to the inch.

Earthquakes in Michigan by Prof. W. H. Hobbs.

In Preparation.

The Geology of Wayne County by W. H. Sherzer.

The Salt Industry of Michigan by C. W. Cook.

The General Geography of Michigan by L. H. Wood.

PROGRESS OF THE TOPOGRAPHIC SURVEY IN MICHIGAN.

The ultimate aim of the topographic survey in Michigan is the mapping of the entire area of the state, 57,980 square miles, in units of 15' of latitude by 15' of longitude, each unit being issued as a separate sheet on a scale of 1:62,500, except in certain areas where for special reasons a larger scale is more desirable.

When the survey is completed we shall possess a topographic atlas of the state which will consist of the unit quadrangles showing besides topography, all highways, railroads, trolley lines, the drainage, natural and artificial, and all permanent cultural features, including location of buildings at the time survey is made, bound together, with a key map on which the relative position of each separate sheet is indicated. It is not necessary to urge before this Academy the value of such an atlas of the state nor the urgent desirability of its completion at the earliest possible moment.

Up to the present time a total of 4,924 square miles, or about 8% of the area of the state has been surveyed including sixteen 15-minute sheets in the Lower Peninsula, and in the Upper Peninsula seven 15' minute sheets, and four special sheets to accompany geologic maps of the iron districts, and the Calumet Special sheet. Of the work done in the Upper Peninsula all has been done at the expense of the U. S. Geological Survey, with the exception of the Marquette sheet which, with the 16 quadrangles in the Lower Peninsula has been made in co-operation with the Michigan Geological Survey.

For the fiscal year ending June 30, 1910, there was available for topographic work $4,000.00 of which amount half was appropriated by the state, and half by the U. S. Geological Survey. The Mason quadrangle in Ingham and Livingston counties was completed and work on the Lansing quadrangle in Ingham and Eaton counties was begun and about half finished.

Four thousand dollars of joint co-operative funds is available for the present fiscal year ending June 30, 1911. During the past summer field work on the Lansing quadrangle was completed and the map is now almost ready for the press. Field work on the Charlotte quadrangle will be begun in the spring and continued through the summer.

In addition to the $4,000.00 of co-operative funds there was appropriated, by the Director of the U. S. Geological Survey on the initiative and personal solicitation of the State Geologist, aided by our representatives in congress, $2,500.00 for topographic work in Michigan for the fiscal year 1910-11. This will largely increase the amount of work which could be done with the co-operative funds alone. However, I have no assurance that this, or even a smaller amount will be granted by the Federal Survey for a period of years, over and above the amount granted under the co-operative plan, although the appropriation was made initially to the beginning of work on four quadrangles in the Northern Peninsula which was requested by the Director to be undertaken at the expense of the Federal Survey.

The co-operative funds permit of the completion of about one and one-half 15-minute quadrangles per year, under the most favorable conditions. At this rate we shall complete the topographic atlas of the state in about 175 years. With ten times our state appropriation, i. e., $20,000.00 per annum, providing that a like amount is appropriated by the U. S. Geological Survey, I estimate that the work can be completed in 15 years. Twenty thousand dollars a year is, in my opinion, not too much to be annually appropriated by the state for this work. The Federal Survey stand ready to match any appropriation the legislature may grant up to $20,000.00.

Other states have outstripped Michigan in their efforts to complete a topographic atlas. The total area of five states has been surveyed, six others have surveyed 70% or more of their total area, 18 others have surveyed over 30%. Only four other states, viz.: Minnesota, Mississippi, Indiana and Florida have so little of their total area surveyed as has Michigan. Of these Florida has 3%, Minnesota and Mississippi each 4%, and Indiana 8%. No other state has greater need for a topographic survey than has Michigan, which in natural resources is second to few other equal areas on the continent.

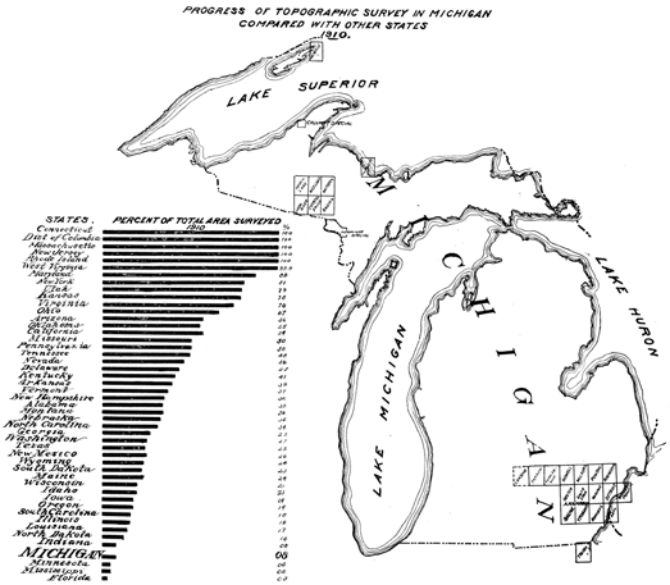
It will be seen by reference to the table below compiled from the annual report for 1910 of the Director of the U. S. Geological Survey, that of the states which co-operate with the Federal Survey in topographic mapping only one, Virginia, appropriates so small an amount per annum for this work as does Michigan, yet it should be noted in making this comparison that Virginia has surveyed 70% of her entire area and Michigan has surveyed only 8%.

TABLE SHOWING PROGRESS OF TOPOGRAPHIC SURVEY IN STATES IN WHICH THE STATE AND FEDERAL SURVEYS CO-OPERATE.

State.	State appropriation.	U. S. appropriation.	Surveyed in 1909-10. Square miles.	Total surveyed to July 1, 1910. Square miles.	Total areas surveyed to July 15, 1910, in per cent.
West Virginia	$15,000	$15,000	.....	24,120	99.8
Maryland	3,000	4,000	321	10,771	88
New York	7,000	7,000	649	40,221	81
Virginia	1,750	1,750	.....	29,980	70
Ohio	15,000	15,000	2,022	27,319	67
California	14,000	14,000	8,183	92,914	59
Missouri	4,500	4,500	320	34,692	50
Pennsylvania	4,238	4,238	629	22,813	50
Kentucky	5,000	5,000	329	16,476	41
North Carolina	2,500	2,500	243	17,661	34
Washington	10,000	10,000	2,228	20,754	30
Texas	20,000	20,000	493	66,807	25
Maine	3,500	3,500	402	7,801	24
Iowa	1,750	1,750	182	10,448	19
Oregon	2,500	2,500	605	18,279	19
Illinois	17,500	12,500	1,136	10,082	18
Louisiana	20,000	6,700	300	8,283	17
Michigan	2,000	2,000	439	4,924	8
Minnesota	10,000	5,000	495	5,582	4

The slow progress of the topographic survey in this state is due to the failure of the legislature to appropriate money in proportion to the value and importance of the work, and in great measure to the apathy of the

engineers, educators, and others who understand the utility and the importance of a completed topographic atlas from both the economic and the purely educational view points. It is necessary that the legislature be convinced of the importance and value of the topographic atlas before it will acquiesce in the expenditure of public money for its rapid completion. Let every resident member of the Michigan Academy of Science constitute himself a committee of one to take this matter up with the senator and representative from the district in which he lives urging the desirability of the early completion of the topographic atlas of the state and much will be done thereby toward securing an appropriation for this work in keeping with its value and importance to the development of the state.



BIOLOGY.

BY ALEXANDER G. RUTHVEX, CHIEF FIELD NATURALIST.

At the general meeting of the Michigan Academy of Science last year, I reported upon the progress of the biological work of the Survey up to that time.* I stated then that four papers were in press, six in preparation, and that a botanical investigation of an area on the west coast of Michigan was planned for the summer of 1910.

In June, 1910, Bulletin I, Biological Series 1, of the Survey was published. This report contained the following four papers:

Pearse, A. S.—The Crawfishes of Michigan, pp. 9-22, 8 plates.

Cook, Mel. T.—The Insects Galls of Michigan, pp. 23-33.

Tinker, A. D.—The Birds of the School Girl's Glen Region, Ann Arbor, Michigan. A study in Local Ornithology, pp. 35-66, 8 plates, 1 map.

Smith, Harlan I.—Preliminary List of the Sites of Aboriginal Remains in Michigan, pp. 67-89.

Four papers based upon survey material and published elsewhere than in our reports also appeared during the year. They are:

Baker, H. B.—Variation in Lymnaea Reflexa Say, from Huron County. 12th Ann. Rept. Mich. Acad. Sci., pp. 60-63.

Ruthven, Alexander G.—Notes on Michigan Reptiles and Amphibians, II. 12th Ann. Rept. Mich. Acad. Sci., p. 59.

Ruthven, Alexander G.—The Mershon Expedition to the Charity Islands, Lake Huron. Science, N. S., XXIII, pp. 208-209.

Pearse, A. S.—A Preliminary List of the Crustacea of Michigan. 12th Ann. Rept. Mich. Acad. Sci., pp. 68-76.

The last paper is to be ranked with our monographs, and was prepared by Dr. Pearse for our use.

I have investigated the status of the other manuscript papers mentioned in the April report, and find that substantial progress has been made in all of them. The report on the biological survey that was made of the sand region on the south shore of Saginaw Bay is in press, and the others will appear as rapidly as they can be finished and edited.

Manuscripts now in preparation that were not listed in the April report are mostly the results of work done last summer or under way at the present time. Dr. C. H. Kauffman reports that he and Dr. L. H. Pennington had excellent success last summer in the botanical work in the western part of the state. Dr. Kauffman was in the field from June 27 to September 30; Dr. Pennington from June 27 to August 27. The field work covered about 350 square miles in Allegan, Ottawa and Van Buren Counties, and copious notes and a large collection of specimens were secured as the basis of a report.

All of the money available from the survey appropriation for the year was put into the botanical work in the western part of the state, but, thanks to the generosity of Hon. W. B. Mershon, we were enabled to send out another party, to the Charity Islands, Saginaw Bay. Mr. Mershon bore the expense incidental to sending five men to the islands for different periods of time last summer, and as a result we were able to make quite an exhaustive investigation of the fauna and flora. The men that we sent up and the groups that they studied were as follows:

N. A. Wood (vertebrates), W. W. Newcomb (butterflies and moths), A. W. Andrews (beetles), Frederick Gaige (ants), and C. K. Dodge (plants). These men worked for their expenses, and to their enthusiasm and energy is due in large part the excellent results obtained. Large collections of the different groups were secured, together with voluminous notes on habitats, etc. The men are now working on their reports, which will be published in various journals under the general title "Results of the Mershon Expedition to the Charity Islands, Saginaw Bay." The first one, the general account, has already

appeared, and the report on the birds, by Mr. Wood, will be published in the June number of the Wilson Bulletin.

In addition to the monographs listed in the last report, we have another in preparation, "The Amphibians of Michigan," by Crystal Thompson and Helen Thompson. This paper is now practically completed and awaiting publication. Two other very excellent papers that are awaiting publication are a catalog of the more recently described species of fresh-water mollusca, by Mr. Bryant Walker, and a bibliography of Michigan archeology, by Mr. Harian I. Smith.

The work proposed for next year is as follows: A few weeks work on the Charity Islands in the early summer to supplement the late summer and early fall work of last year, a preliminary investigation of the mammals in the region of Osceola county, and the collecting of botanical material from various parts of Michigan for a state herbarium.

In closing I would like to make a plea for more cooperation on the part of the members of the Academy. It is of the first importance to us to have exhaustive data on the occurrence of each species within our limits, but we have experienced considerable difficulty in securing such material. From no region have we enough data, and from many regions we have few or no records for most groups. Thus any records of occurrence, even though they are of our commonest forms, are valuable. I wish every teacher of biology, or other interested person, in the state would get into the habit of sending us such specimens or notes as they have the opportunity to obtain. We maintain a record bureau at the Museum, and every reliable record received is preserved, whether or not it comes to us with a specimen.

*12th Ann. Rept. Mich. Acad. Sci., pp. 54-58.

PRELIMINARY REPORT ON THE SALT INDUSTRY OF MICHIGAN.*

C. W. COOK.

The salt industry of Michigan has had a long and varied history. Before the admission of Michigan into the Union, attempts were made to manufacture salt from the saline waters of springs, both in Macomb county and at Saline in Washtenaw county. The statehood act of 1836 permitted the reservation by the state of seventy-two sections of saline lands and for the next twenty odd years numerous endeavors were made to develop these salt springs. However, the efforts met with continual failure and the lands were finally disposed of.

A small amount of salt was manufactured, in 1842, at Grand Rapids by the Hon. Lucius Lyon.[1] The; price of three dollars per barrel, obtained at this time, enabled him to operate without loss but at no profit and the attempt was soon abandoned.

The real beginning of the industry dates; from 1859, when the first successful well was sunk at East Saginaw by the East Saginaw Salt Manufacturing Co. From then until the present, the growth has been practically continuous, until, in 1905, Michigan assumed first place in production, and in 1908, passed all other states in the value of the produce.

This progress has been marked by the rise and fall of various districts. The Saginaw Valley, with the industry centered at Saginaw and Bay City, became the first important district. From here, the industry soon spread to Midland, St. Louis, and the towns along the lake shore, such as Caseville, Pt. Crescent, Pt. Austin, New, River, Pt. Hope, Harbor Beach, and White Rock on the south side of Saginaw Bay; and Tawas City, East Tawas, Oscoda, and Au Sable to the north.

These plants first used the kettle process. It soon gave way, how-ever, to the open pan and grainer. Most of the salt blocks were operated in connection with sawmills, the refuse (saw-dust and slabs) being used for fuel in the kettle and pan blocks, while exhause steam was employed in the grainers. This undoubtedly lead to the waste of a large amount of lumber. As one former operator told, me, "Give us plenty of saw-dust and slabs, we don't care for the lumber" was a common saying.

The dependence of salt upon the lumber industry is shown by the disappearance of all of the lake shore plants. In fact, even some of the towns, such as Pt. Crescent and New River, are now but memories. In the Saginaw Valley itself the industry is fast disappearing, so that, where once there were over one hundred plants in operation, now but nine, including a small plant at Mt. Pleasant, remain.

*Published with the permission of the State Geologist.

[1]Winchell, A., "On the Saliferous Rock and Salt Springs of Mich." Am. Jour. Sc. Vol. 34, 2nd series, 1862, p. 309.

Correlative with the decline of the Saginaw Valley industry, has been the rise of the Ludington-Manistee district, and the region along the Detroit and St. Clair rivers.

At present, the Ludington-Manistee district leads in production, having produced, in 19091, two-thirds of the entire output of the state. Here the industry is likewise associated with the lumber industry, but one plant, the Anchor Salt Co., of Ludington, operating independently of the saw-mills. Two processes are in use, the grainer and the vacuum pan, and the product, which is sold largely in bulk and barrels, is what is known as common salt in counter distinction to table salt. The Stearns Salt and Lumber Co. of Ludington, however, is planning to install apparatus for the manufacture of table salt.

The first attempt, in later years, to manufacture salt in the Detroit-St. Clair Rivers district was made at Mt. Clemens. While this effort was a failure, owing to the fact that the well did not pierce the rock salt but stopped in a brine-bearing stratum above, the brine of which was too impure to be successfully utilized in the manufacture of salt, it is especially interesting in that it lead to the discovery of the remarkable curative properties of the Mt. Clemens mineral waters.

When later rock salt was found, plants were established at many points along the St. Clair River, and then south of Detroit. So that today, companies are operating at Pt. Huron, St. Clair, Marine City, Delray, Ecorse, Wyandotte and Oakwood. In addition to these brine plants, rock salt is being mined at Oakwood by the Detroit Salt Co. In this district, all types of manufacture, employed in Michigan, may be seen. Thus we find the open pan, grainer, vacuum pan, and Alsberger systems all in operation. The majority of the plants also make table salt.

With the exception of the rocksalt produced at Oakwood, salt is manufactured in Michigan by the evaporation of brines, both natural and artificial. At various times, three different natural brines, each of which is obtained from a sandstone, has been employed. These brine-bearing sandstones are the Parma, the Napoleon, and the Berea.

The Parma brine, while no longer used on account of its being weaker than the underlying Napoleon brine, is characterized by its purity. As may be seen from the analyses in table I, it is distinguished from the Napoleon and Bera brines by a higher percentage of calcium sulphate relatively to the early chlorides. This brine was one of the first used in Michigan and its utilization was limited to the Saginaw Valley.

[1]Report State Salt Inspector, 1909.

TABLE I.

	1.	2.	3.	4.	5.
Calcium sulphate	3.961	.....	.....	0.129	0.33
Calcium chloride	5.302	41.1	83.00	31.274	110.00
Magnesium chloride	4.115	17.6	31.00	15.675	33.47
Magnesium bromide	.....	0.712	1	.....	.....
Ferric oxide and Alumina	.....	.....	.....	.....	1.14
Ferrous chloride	.....	0.050	Trace	.....	.....
Sodium chloride	152.674	167.3	141.00	176.161	186.19
Total solids	166.052	226.675	256.00	232.803	331.73

1, 2, 3, and 4 represents grams per kilogram.
5 represents grams per litre.
1. Parma brine from Gilmore well, Bay City, Michigan. Analysis by Dr. A. C. Goesmann, October, 1862. (Geol. Sur. of Mich. Vol. III, p. 181.)
2. Napoleon brine from Saginaw Salt Co., St. Charles, Michigan. Analysis by J. C. Graves, furnished by O. C. Diehl.
3. Marshall brine from the Dow Chemical Co., Midland, Michigan. Analysis furnished by H. W. Dow.
4. Per a brine from the Ayres well, Pt. Austin, Michigan. (Geol. Sur. of Mich., Vol. III, p. 183.)
5. Berea brine from the North American Chemical Co., Bay City, Michigan. (Geol. Sur. of Mich. report for 1905, p. 388.)

The Napoleon brines (Nos. 2 and 3, table I) which are the source of the salt of the Saginaw Valley, are characterized by the small percentage of calcium sulphate and the presence of considerable amounts of bromine. It will be noted that the amount of bromine and earthy chlorides increases relatively to the sodium chloride as we go toward the center of the basin. While no analyses are available, Dr. Dow informs me that there is a considerable increase at Mt. Pleasant over Midland.

The Napoleon sandstone is found at a depth of about 650-800 feet at Saginaw, 800 feet at Bay City, 1,300 feet at Midland, and 1,400 feet at Mt. Pleasant.

Besides salt, a number of other products are obtained from this brine. The Dow Chemical Co. of Midland manufactures a large number of chemicals, among which may be mentioned, bromine, bromides, bleaching powder, and chloroform; the Van Schaak Calcium Works of Mt. Pleasant produces bromine and calcium chloride; the Saginaw Plate Glass Co. has recently installed apparatus to recover the calcium chloride from the mother liquors from the salt block; and the North American Chemical Co. of Bay City uses the brine in the preparation of chlorates.

The Berea brine (Nos. 4 and 5, table I) was used by the plants along the lake shore in Huron and Iosco counties. It contains an appreciable amount of bromine, not shown in the analyses, which was recovered from the bittern at some of the plants.

There are other Michigan brines, which, although they have not been used for the manufacture of salt, are, at present, attracting considerable attention on account of their high content of potassium. Of these, two may be mentioned. The first is from the deep well at Harbor Beach. It is found at a depth of 1875 feet in what Lane[1] has called the Monroe formation with a question mark. The second is from Muskegon. It is struck at a depth of 2,030 feet in what is probably the Dundee limestone. The analyses follow:

	1. Grams per liter.	2. Grams per kilogram.
Calcium sulphate	.9936	4.22
Calcium chloride	62.6636	54.10
Magnesium chloride	5.3542	14.97
Magnesium bromide	24.8400	2.37
Potassium chloride	37.7788	22.16
Sodium chloride	179.2391	158.17
Silica	.7303	.....
Total solids	311.5996	255.95

1. Brine from well of the Sand Beach Mineral Springs Co., Harbor Beach, Michigan. Analysis by S. P. Duffield. (Geol. Sur. of Mich., Vol. V, Part II, p. 82.)
2. Brine from the Ryerson well, Muskegon, Michigan. Analysis by Dr. C. A. Goesmann, September, 1883. (Geol. Sur. of Mich., report for 1901, p. 233.)

[1]Geol. Sur. of Mich., Vol. V, Part II, p. 82.

The artificial brines, employed in the Ludington-Manistee and Detroit-St. Clair rivers districts, are formed by solution of the rock salt of the Salina formation. In the former the flow of ground water in the super-imposed strata is sufficient to form the brine and the pumping is done mostly with compressed air. At most of the plants in the southeastern part of the state, it is necessary to pump water into the wells and the brine when formed is forced up by water pressure.

At Ludington and Manistee the salt layer has a thickness of 20 to 30 feet and is found at a depth of about 1900 feet at Manistee and 2,300 feet at Ludington. It has been thought that but one bed existed in this district.[1] However, the No. 4 well of the Anchor Salt Co. at Ludington shows the presence of four beds, respectively 20, 12, 7, and 5 feet in thickness. The extent of this area is not known, but wells at Frankfort and Muskegon, which should have pierced it had it been present, failed to disclose any salt.

The salt beds of the southeastern area are much greater both in number and thickness, one being over 250 feet thick. In a general way they seem to dip away from the Cincinnati anticline and to increase in thickness along the dip. How far this increase continues we do not know, as no records are available beyond Royal Oak,

where nine beds have an aggregate thickness of 609 feet.

Another area in which rock salt has been found in considerable quantities, but has not, as yet, been exploited, is in the vicinity of Alpena. Five beds of salt with streaks of anhydrite here show an aggregate thickness of over 300 feet.

Although we have no positive evidence on the subject, from a consideration of the general geology of the state and the apparent increase in thickness of the beds along the dip, it seems reasonable to believe that these three areas are but portions of one larger area. Rock salt is therefore likely to be found anywhere within lines joining the outer limits of the different proved areas.

[1]Lane, Report for 1908, p. 59.

The composition of the brines may be seen from the following analyses:

	1.	2.
Specific gravity	1.138	.....
Calcium sulphate	5.66	2.3
Calcium chloride	.....	1.0
Magnesium sulphate	.....	.....
Magnesium chloride	2.015	0.7
Sodium chloride	247.4	265.7
Total solids	255.075	269.7

The above represents grams per kilogram.
1. Filer and Sons, Filer City, Michigan. Analysis by W. and H. Heim, Saginaw, Michigan. Analysis furnished by Mr. E. G. Filer.
2. Michigan Salt Co., Marine City, Michigan. Analysis by Robt. E. Devine, Detroit, Michigan. Analysis furnished by Mr. S. C. McLouth.

As to the methods of manufacture, one, the open pan, employs direct heat, the others use steam, either live or exhaust.

The open pan system may be thus briefly described. The pans, which are constructed of boiler plate, are about seventy feet long, twenty-five feet wide, and twelve inches deep, and have sloping sides to permit of the salt being raked onto the draining boards. The heat is furnished by a furnace placed at one end, the pan above being protected by a brick arch. The heated gases pass back under the pan to the chimney. In some cases, the chimney is placed beside the furnace, the gases, by means of a return flue, being made to traverse the length of the pan twice.

The grainer consists of a rectangular vat, 100-160 feet long, 8-18 feet wide, and 22 inches deep, in which are placed steam pipes. The salt when formed is removed either by hand with shovels or by automatic rakers.

The vacuum pan consists of a vertical steel cylinder tapering at both ends, in the middle of which is a steam belt, through which the brine tubes pass, with a large tube in the center. A partial vacuum is maintained in the pan so that the boiling point of the brine is considerably lowered. If the pan is run "single effect," the steam formed by the evaporation of the brine is taken care of by a condenser. On the other hand, when two or more pans are run in "multiple effect" the steam formed in the first pan is conducted to the belt of the second pan on which a greater vacuum, is carried and is used to furnish the heat for the second pan. The "triple effect" pan is in successful operation at a number of Michigan plants, and in New York state a "quadruple effect" is being operated. The salt, as it forms, drops to the bottom of the pan and is removed by a bucket elevator.

With respect to the Alsberger system, I shall not go into details but merely state that the principle involved is that of superheating the brine under pressure and then running it into pans in which the deposition of the salt takes place without the further addition of heat. Revolving rakers scrape the salt into a well from the bottom of which it is drawn off into a centrifuge in the form of a paste and separated from the water.

In the manufacture of table salt, the common salt is dried by passing-it through a rotary kiln. The dried product is then separated into the different sizes, such as table, butter, cheese, etc., by means of tubular screens or patent separators. To some of the fancy brands of table salt small amounts of calcium or magnesium carborate are added to prevent caking.

The salt production of the state for 1908, as given by the U. S. Geological Survey, was 10,194,279 barrels valued at $2,458,303. This includes the brine salt worked up into soda ash and other products. The production for the same year as given by the state salt inspector was 6,247,073 barrels.

Ann Arbor, Mich., April, 1911.

THE EXTENT OF THE ANDERDON BEDS OF ESSEX COUNTY, ONTARIO, AND THEIR PLACE IN THE GEOLOGIC COLUMN.

REV'D THOMAS NATTRESS.

Considerable interest has centered in the Anderdon Limestone Beds of Anderdon Township, Essex County, Ontario, since Garbau pronounced them hitherto unrecognized in 1907 and gave to the beds the name they now bear. That interest was intensified by Professors Sherzer and Grabau when they claimed to have identified this limestone with certain problematical beds deep down in the Silurian strata in the Salt Shaft at South Detroit.

A year ago in presenting before the Academy a paper on The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area, I took occasion to adduce some suggestive evidence that the supposed intercalated beds at the salt shaft and the Anderdon beds have each their own independent horizon.

Since then it has fallen to my lot to superintend the taking out of thirty drill cores to determine the extent of these limestone beds in Anderdon and Maiden townships. Ten other cores had already been taken out in and near the Amherstburg Quarries in Anderdon. In addition to these forty drill cores, there are three quarry holes through the high grade limestone, to facilitate the estimate. The accumulated evidence has too broad a bearing not to be presented in the endeavor that has

been yours and mine to solve the problems of the Detroit river area.

Professor Grabau has himself differentiated the Anderdon limestone in his Stratigraphic and Palaeontologic Summary of the Monroe Formation. Under the head of "Upper Monroe Faunas" he groups as a unit the faunas of the Flat Rock, Anderdon and Amherstburg (Detroit river bottom) beds. Of the faunas of this supposed unit he has said: "Its most characteristic feature is its Devonic element." And: "If the fauna were considered by itself it would probably be pronounced a Scoharie or an Onondaga fauna without a moments hesitation, though there is a considerable Siluric element."

Taking the cut on p. 541 of the "Proceedings of the Albuquerque Meeting, (Fig. I. — Section of the Detroit river)," as setting forth the supposed relationship of the "Flat Rock, Anderdon coral limestone and Amherstburg Dolomite," the Flat Rock below, the Amherstburg Dolomite above, the Anderdon between, —— then the "considerable Siluric element" ought to be very evident in the sandwiched Anderdon limestone in order that it should still persist in the overlying new-named Amherstburg. But whereas the Siluric fauna characterizes the Flat Rock and the Amherstburg Dolomite of the Detroit river bottom, it is characteristically absent from the Anderdon limestone beds.

*The Monroe Formation; Mich. Geolog. and Biolog. Survey, 1909, p 217.

Moreover, the Anderdon beds do not extend across Detroit river from the Amlierstburg quarry to the Sibley quarry as figured in the cut referred to. This I have contended before and shall be able to set forth further evidence. The Dundee (Corniferous) limestone does *not* extend westward to the Detroit river as thus figured, and *does* form the surface extension over the great part of the Amherstburg quarry in Anderdon, where the cut shows only Anderdon coral limestone —— out of relation.

Analyzing Grabau's faunal unit, this result is obtained:

Flat Rock Dolomite:

Stromatoporoidea, 0.	*Anthozoa*, 3.
Brachiopoda, 0.	*Bryozoa*, 0.
Pelecypoda, 0.	*Gastropoda*, 0.
Cephalopoda, 0.	*Trilobitae*, 0.
Annelida, 0.	

The Anderdon Limestone:

Stromatoporoidea, 6.	*Anthozoa*, 12.
Brachiopoda, 2.	*Bryozoa*, 0.
Pelecypoda, 1.	*Gastropoda*, 2.
Cephalopoda, 0.	*Trilobitae*, 0.
Annelida, 0.	

The Amherstburg Bed (dolomite) of Detroit River:

Stromatoporoidea, 2.	*Anthozoa*, 13.
Brachiopoda, 12.	*Bryozoa*, 1.
Pelecypoda, 3.	*Gastropoda*, 8.
Cephalopoda, 4.	*Trilobitae*, 1.
Annelida, 1.	

Of the *Stromatoporoidea* 2 of 6 are in common between the Anderdon limestone and the Amherstburg dolomite.

Of *Anthozoa* there is 1 in common throughout, and but 4 in common between the Anderdon limestone and the Amherstburg dolomite, out of a total of 21.

Of *Brachiopoda* there is but 1 of 13 in common between the Anderdon limestone and the Amherstburg dolomite.

Bryozoa is represented in the Amherstburg dolomite alone.

Of *Pelecypoda* but 1 out of 3 is in common between the Anderdon and the Amherstburg.

Of *Gastropoda* there is nothing in common, though 10 species have been noted.

Cephalopoda, *Trilobitae* and *Annelida* are represented in the Amherstburg only, in *Grabau's list. I have since found *Proetus crassimarginatus*, in the Anderdon limestone.

I submit that here is an internally exclusive "unit."

*Michigan Geological and Biological Survey, 1909, The Monroe Formation,——Grabau and Sherzer.

Nor is that the end of the comparison. Of 23 species (5 genera) identified in the Anderdon limestone and the coral bed of the salt shaft at Delray, but 7 are in common to these, one only of which is found in the dolomite of the Detroit river bed in the vicinity of Amherstburg.

Having presented *evidence to show what the Anderdon limestone beds are not, I shall attempt to show what these beds are,—how they are deposited, and how they are related.

*See Michigan Academy of Science report, 1910. "The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area."

THE MALDEN VALLEY.

The drill holes put down to determine the extent of the Anderdon limestone have disclosed a basin and a valley leading to it from the south, together containing the "Anderdon Beds" (Grabau). I have presumed to name this valley the Maiden Valley of the Anderdon Limestone, inasmuch as it was first followed up from a starting point in Maiden township. I have followed up this valley some 6,500 feet from that starting point of investigation to where it expands into a basin, the central area of which is the Amherstburg Quarry property.

Cross sections prove the valley formation and show the relation of the Anderdon Beds to the underlying Silurian

dolomites. A complete cross section is constituted by test holes numbered 9 to 13, from east to west.

In No. 9, in an old Detroit river channel, there is a Silurian surface extension. Analyses show an average of 56.75 $CaCO_3$.

About 800 feet west of it No. 10 showed Anderdon Beds at the surface, one foot in depth, resting upon a transitional rock, which in turn rests upon Silurian dolomite. The transitional here averages 60.56 $CaCO_3$, and is 8 feet in depth; the dolomite 54.19 tested to a depth of 21 feet.

No. 11 is about 700 feet west of No. 10: Anderdon 13 feet, averaging 93.76 $CaCO_3$; Transitional, 8' 6", 63.37; Silurian dolomite 5"10", 54.87.

No. 12, about 700 feet west of No. 11, shows 10' 7" of Anderdon, averaging 95.60 $CaCO_3$; Transitional, 7' 9", 62.44; dolomite not penetrated.

No. 13 is about 700 feet of No. 12. Here there is but 2 feet of Anderdon Beds, averaging 94.72 $CaCO_3$; Transitional 7' 5", averaging 57.53; Silurian dolomite penetrated 11' 7", averaging 50.39 $CaCO_3$.

Some 6,000 feet west of No. 13 is the Detroit river bed, with Silurian dolomite extension,—a surface that would probably extend as a surface extension as far east of Detroit river as to a point 300' to 400' west of No. 13 test hole.

A review of this cross section shows:

(1) The Anderdon Beds in the Maiden Valley banking up against Silurian dolomite, east and west;

(2) A Silurian surface extension both east and west of the Anderdon Beds, in the old Detroit river channel eastward and in the bed of the present Detroit river westward; and, on reference to elevations,

(3) A Silurian dolomite synclinal between the Canadian channel of Detroit river immediately opposite Amherstburg (elevation 552.5 +) and No. 10 test hole, (elevation of Silurian surface, 563.2) in close proximity to the eastern edge of the Anderdon;

(4) A similar syncline east of that again, immediately; (5) Disturbance of former levels prevailing during the time of depositing of the Transitional overlying the dolomite, during which time the present Silurian sync-line was at least 700 feet wider than it is now, on the east side—for within that approximate distance the Transitional (of which there is 8 feet in depth at No. 10 hole,) has shored up;

(6) Maximum thrust of uplift in close neighborhood of No. 10;

(7) Change in elevations across the whole cross section distance of the Anderdon beds, with possible exception of the extreme western shore; and

(8) Suggests the reason for the prevailing increased depths of boulder till from the eastern limit of the Maiden Valley of Anderdon limestone, westward to Detroit river,—an ascertained increase of depth of from 12' 0" to 15' 6" to 21' 3" to 28' 6" to 40' 0" at intervals of about 700 feet.

TRANSITIONAL ROCK.

The characteristics of the Transitional rock at the base of the Anderdon limestone, and the reasons for describing it as transitional are these:

(1) It lies between a limestone deposit of the purest quality and an equally pronounced Silurian dolomite, and is itself a dolomitic limestone.

(2) It is not local but extends over the whole area of, and beyond the outer edges of, the overlying Anderdon limestone; requiring, therefore, consideration as a distinct deposit; and having characteristics that relate it to both the Devonian and the Silurian.

(3) Like the Anderdon limestone above it, this rock carries the Devonian form, of calcium carbonate crystal, dog-tooth spar, by contrast with the Silurian scalenohedra of calcite.

(4) Yet, in several instances, and at low horizons in the formation the crystals filling the cavities of the rock appeared to be a compromise between the two forms.

(5) In addition to that fact, the prevailing browns, blue-grays, and the dullness of the grays and drabs are Silurian characteristics.

(6) There were no Silurian forms distinguishable, nor either sulphate or carbonate of strontia, nor any gashed or acicular rock; all of which, with scalenohedra of calcite and high magnesia characterize the underlying strata.

(7) There is, as in the Silurian, at many elevations, considerable dark-lined lamination and frequent irregular lines of deposit.

(8) In three instances only does the $CaCO_3$ average of the transitional rock from a given test hole fall below 60%, and that where too few samples were taken. From all the rest of twenty-one averages the percentage of calcium carbonate is from 60.56 to 69.04. The average over all—in a distance of two miles—is 63.49 $CaCO_3$. This fact establishes the Transitional as a better calcium: carbonate rock than is the heavy-bedded dolomitic limestone which lies second above it and forms the base of the Corniferous. This latter dolomitic limestone analyses about 60% $CaCO_3$. Like it, the Transitional appears to be almost fossil free.

I submit that this rock is transitional in character, with predominating Devonic features.

Before considering the question of transitional rock at further length let me present some facts of

THE BASIN OF ANDERDON LIMESTONE,

of which the Amherstburg quarry property forms the central area.

Thus far—except in viewing the entire distance of the Transitional— only the Maiden Valley of Anderdon beds has been considered, by way of which the supply of this limestone seems to have come in from the southward.

The Amherstburg Quarry basin of Anderdon limestone is an expansion of the Maiden Valley, circular in form, with a bulging western side. It seems to have had no other communication with the outer sea, in Anderdon time, than this valley. Cross sections will show the manner of deposit to best advantage. Two will suffice, one from east to west, and one from N. x NW. to S. x SE. Test* holes 26, "3," "8," and 21 are from east to west in order. No. "8" is as nearly as may be the center of the basin. No. 26 marks the eastern limit of the deposit, No. 21 is 1,500 feet west of this center and No. "3" is 1,350 feet east of center. Were there one more test made as far west of center as No. 26 is east of it, at the rate at which the depth lessens westward there would probably be about the same depth of Anderdon beds in that as there is in No. 26.

No. 20 test was the most westerly put down and though somewhat out of line for this cross section is yet available for comparison. (It is also interesting as establishing a bulging west side.)

Anderdon at 26, 1' 3",
Anderdon at "3," 16' 7",
Anderdon at "8," 28' 0",
Anderdon at 21, 15' 9",
Anderdon at 20, 6' 2".

This section shows an east and west shoreing up of Anderdon high grade limestone.

*Plain figures indicate tests of the survey of Sept, to Dec., 1910; figures in quotation indicate tests of 1909 survey.

A MODIFIED ANDERDON.

During Anderdon time, and while these beds were being deposited, extraneous influences were exerted upon the Anderdon material about the outer edges of the basin, sometimes reaching across its full width—or rather would I say, meeting in the centre. Just what these influences were is not so easy to say. The effect exerted is very palpable. In some cases several feet in depth of the Anderdon beds are reduced to the quality of an ordinary good limestone; in other cases a silicated limestone was produced; in still other cases the slow depositing limestone has been swamped with magnesia and silica until a dolomite resulted. Whether the magnesia and silica were due to an inwash from a Silurian sea to the west, north, northeast and east, facilitated by a lowering of the confining Silurian anticlinal dam by earth movements from time to time, alternating with unlift; or whether the source of the extraneous matter was a Silurian land area, may be open to question. Very considerable depths of unmodified pure Anderdon limestone alternate with deteriorated parts. Especially is this true toward the centre of the basin, indicating that the influence was one felt chiefly along shore.

The silication is not so difficult to account for. In part it is from the same source without doubt. But when it is observed that the most heavily silicated spots are on the shoulders of the Maiden Valley where it expands into the basin, and also directly in line with the slight wash from the inflow of the valley, the chief cause of silication has been identified. The valley itself has felt none of these influences to any perceptible degree.

Should it be that the magnesian influence was due to the sea, then it follows that Silurian conditions prevailed northward, westward and to the northeast whilst the Maiden Valley communicated with a sea to the south in which Devonian conditions had already become established.

A N. x N. NW. to S. x S. SE. Cross Section shows the same basin formation, with No. "8" test hole as centre, four tests to the southeastward of it and two to the northwestward. (In no case has the west side been tested out to the same extent as the rest of the area, because of heavily increased depth of boulder till.)

The test holes of this cross section are, in order from S. x S. SE. to N. x N. NW., Nos. 15, 17, 22, "9," "8," "4" and "5." The distances between, in same order, approximately 1,000', 450', 425',. 525', 1,725', and 330'.

Anderdon at 15, 0' ½",
Anderdon at 17, 5' 6",
Anderdon at 22, 23' 6",
Anderdon at "9," 42' 0",
Anderdon at "8," 28' 0"',
Anderdon at "4," 11' 3",
Anderdon at "5," 8' 6".

Modified Anderdon at 15, 0' 0",
Modified Anderdon at 17, 22' 1"
Modified Anderdon at 22, 22' 10",
Modified Anderdon at "9" 9' 0",
Modified Anderdon at "8" 23' 6",
Modified Anderdon at "4" 29' 4"
Modified Anderdon at "5" 27' 0".

Transitional Rock at 15, 3' 8",
Transitional Rock at 17, 10' 6",
Transitional Rock at 22, 4' 6"+,
Transitional Rock at "9" 8' 0",
Transitional Rock at "8" 11' 6",
Transitional Rock at "4" 4' 8",
Transitional Rock at "5" Not penetrated.

The Anderdon shows distinctly the basin shape of deposit. On comparing the Anderdon + Modified Anderdon depths in No. "8" and No. "9," it will be noted that No. "9" has felt the deteriorating influences much less than the No. "8" area. It shows less Modified Anderdon and more high-grade limestone. Consequently, whether at base or surface, the Modified Anderdon also shows the basin form of deposit in the cross section.

A consideration of the elevations in the same test holes in the same order gives the same results:

Elevation of Anderdon at 15, 570.36 A. T.
at 17, 570.63,
at 22, 566.00,
at "9," 558.26,
at "8," 547.50,
at "4," 576.15, and
at "5," 563.80;

Elevation of Modified Anderdon:
at 17, 565.13,
at 22, 543.50,
at "9," 526.26,
at "8," 519.50,
at "4," 564.90, and
at "5," 553.30;

Elevation of Transitional Rock:
at 15, 570.32,
at 17, 543.05,
at 22, 519.66,
at "9," 507.26,
at "8," 496.00,
at "4," 535.56,
at "5," not penetrated.

The basin, as shown by elevations of the Anderdon at No. 15 and No. "5"—has a lip rim, occasioned by uplift of the inner area in relation to the outer.

The evenness of the basin shape is evident if it be remembered that the distance from No. "8" to No. "4," 1,725 feet, is more than three times any other separating distance; that Nos. 17 and 15 are 1,000 feet apart; and that another test is needed about 350 feet N. x N. NW. of No. "5" to contrast with No. 15 at extreme S. x S. SE., for a complete comparison.

A cross section from NE. to SW., from the Sol White quarry hole, by way of the Amherstburg quarry limestone cut, test holes No. "8" and No. "7," to No. 20 shows the same basin-shaped deposit.

EARTH MOVEMENTS OVER THE ANDERDON AREA.

The evidences of earth movement over the Anderdon limestone area during Transitional, Anderdon and Corniferous time are of very pronounced character.

Included in the transitional rock shown up by cross section of the Maiden Valley already presented, is a deposit characterized by quantities of calcium carbonate crystal, in bulk, so to say. In drill core No. 10 this is 48 inches in depth; in No. 11, 700 feet west it is 36 inches in depth; in No. 12, 700 feet west of No. 11, there is but 26 inches; and in another 700 feet it has disappeared. This assuredly indicates one of two things: a deep side to the valley—which does not seem to account for all the facts in the case; or a gradual change of elevation during continuance of the deposit.

Subsequent to Anderdon time, and in what has hitherto been recognized as mid-Corniferous, a movement of a different kind has taken place. This time it is not tilting, but there appears to have been a thrust that reached its maximum along the eastern side of the Anderdon deposit—both valley and basin. The evidence is of two kinds: (1) *Change of elevation along cross section lines, and (2) a shattered condition of the eastern edge of the deposit. Every cross section shows a gradual slope to westward across the entire width of what must; in the order of things, have been a slightly concaved surface at the close of Anderdon time. In the Amherstburg quarry basin of the Anderdon material this movement is evidenced by relative differences of elevation, though the basin surface is still preserved in any but an east and west section.

*Test boles 10 to 13, 2100 feet from east to west, show elevations of Anderdon beds: 571.30, 567.80, 561.85, and 554.50.

Test holes 29 and 27, in east to west section, 700 feet, snow 574.40 and 563.90. Nos. 15 and 16, 780 feet east to west, 570.36 and 565.70. Test holes "1," "9," "7," and 19 and 20 show 574.33, 558.25, 538.10, 536.66 and 536.66.

SINK HOLES.

The shattered condition of the eastern edge of the Anderdon deposit is evidenced by a series of twenty or more sink holes in the land surface. In localities these are grouped together in numbers. In every case where the rock below has been investigated it has been found to be fissured and broken. Along the west side of the deposit the depth of stripping impervious to water would in itself explain the absence of sink holes. There does not, however, appear to be the same shattered condition of the rock, though the core-drill occasionally revealed a crack.

A LINE OF FAULT.

Associated with this line of sink-holes, and parallel with it, is a series of mineral springs highly charged with sulphur, that would seem to show a line of fault. This line traverses the old Detroit river channel immediately east of the Maiden Valley of Anderdon limestone where the surface extension is entirely of Silurian dolomite.

THE MAXIMUM OF THRUST.

When the depositing of Anderdon sediment ceased, it would seem to be evidenced by a maximum depth of overlying Corniferous that the lowest elevation within the Anderdon basin—and approximately the center of the basin—corresponded closely with No. "8" test hole, at which spot there is still the lowest elevation (547.50) of Anderdon within the basin.

And at this precise spot the Corniferous has a higher elevation than any other part of the entire surface in question—unless it be between No. "8" and No. "9" which, together with it, has felt the maximum of thrust. The disturbed elevation of the Corniferous surface of itself proves earth movement. (Ascertained elevations: 578.20, 584.50, 561.10, 555.60, and 538.00.)

If there has been any earth movement strictly within Anderdon time the evidence is to be found in the

Modified Anderdon. If that modification was due to movement and not to the influence of an adjacent land area round about the basin, then it proves in that case a successive lowering and raising of the surrounding Silurian dam that confined the Anderdon waters and excluded—except by intervals—the waters of a sea in which older conditions still persisted.

THE DEPTH OF BOULDER TILL.

The depth of boulder till on the Detroit river side of the line of highest elevations throughout the length of the Anderdon deposit, stands definitely related to the interposed rock barrier to the ice sheet in its forward movement. From east to west across the basin, 3,300 feet, the *depths of till are these:

10' 2", 14' 0", 21' 6", 32' 6", 50' 0".

Along the †complete cross section of the valley, east to west 2,100 feet: 12' 0", 15' 6", 21' 3", 28' 6", and, in another 1,000 feet westward along the Silurian dolomite surface, 40' 0".

On the other hand the glacial detritus has banked up against this same barrier on the east side of it, giving depths in ‡reverse order: 28' 6", and 10' 2"; 17' 0" and 9' 0".

We have thus, doubtless, come upon the explanation of the old Detroit river channel already named: First, a shallow Silurian synclinal dip; then a rock elevation interposed in the path of the glacier, consisting of a low Silurian anticlinal bank, with Transitional and Anderdon rock superimposed, and all of this elevated by a thrusting movement.

*Test holes "1," "9," "7," 19 and 20.

†Test holes 10, 11, 12, 13, and the Borrowman well.

‡Test holes Nos. 26 and "1"; Nos. 5 and 29.

CORNIFEROUS AND ANDERDON MATERIAL.

All the Anderdon limestone material seems to have come in from the south, as has been already stated. Because of the greater depth of the deposit within the cul de sac basin as compared with the supplying valley from the south another valley was suspected leading to the eastward from the basin. That side also was thoroughly tested in the hope of finding such a valley. There is a valley—but not of the supposed age. It carries only Corniferous material. That there is a valley of shallow dimensions goes to show a slight letting down of a surrounding anticlinal tongue of Silurian age which has admitted the Corniferous sediment from the eastward, none of which came in by way of the Maiden Valley; around the tip of which upward fold of Silurian, and toward the south, the Anderdon has circled about, with normal depth, to cross Detroit river in the neighborhood of the upper end of Grosse Isle where there is a showing of Corniferous at the surface, to be again quarried, in its normal depth, in the bottom of the Sibley quarry, almost opposite the phenomenal depth in the Amherstburg quarry.

A cross section of the whole Detroit river area between these two quarries would show nothing of the Anderdon beds from shore to shore of the river. Much less would such cross section show the Detroit river bottom bed of dolomite to overlay Anderdon limestone—to which river bottom strata Grabau and Sherzer have given the name of Amherst-burg Dolomite. Neither will it show Sylvania. Sandrock at the base of Flat Rock dolomite over this area. Nor are the strata of the Detroit river series of Upper Monroe age, except in the upper reaches of the river; and except as the Upper Monroe strata round the head of the extreme northerly limit of the Cincinnati anticline and circle back to southward. On the contrary, and with the exception noted, the characteristics of these strata are those of the Lower Monroe. Compared with the Ballville section of the Ohio Greenfield dolomite this rock also is* "a light-colored dolomitic calcilutite." Like the Lower Monroe beds of Maryland these beds also are †"nearly all calcilutites, mostly thin-bedded, well stratified." As in the case of the Raisin River dolomite, at a given horizon *"hemispherical masses protrude . . . having a finely laminated, concentric structure and apparently concretionary in their structure;" and, "'locally the beds contain patches of iron pyrite." The upper beds are almost fossil-free, which will not be said to be a characteristic of the Upper Monroe strata. And, in addition, the sharp directly southward dip of the strata in all the central part at least of the area in question is in itself a statement of the fact that here is the rock against which the Upper Monroe banks, stratum upon stratum, with dip swinging from westward to northward in Monroe and Wayne counties.

One further remark about the age of the Anderdon limestone beds. Professor Grabau has emphasized their Devonic affinities. I have shown that these beds do not sandwich between two dolomities; that they rest upon a dolomitic limestone transitional in character and Devonic in its chief characteristics; and that they are Devonic in chemical properties, analyzing in some instances 99.55 $CaCO_3$. And, whereas †Grabau describes "the Monroe beds and underlying formations (as) all involved in slight folding *which took place in post-Monroe and pre-Dundee times*," I have shown the Anderdon limestone beds occupying the synclinal space between two of these lateral folds.

Altogether it would appear that the Anderdon Limestone beds have been wrongly classed as Siluric; in short that they are of Devonic age.

Amherstburg, Ontario, March 28th, 1911.

*Stratigraphy, Structure and Local Distribution of the Monroe Formation; by Professors W. H. Sherzer and A. W. Grabau.

†"Correlation of the Monroe Formation of Michigan, Ohio and Canada with the Upper Siluric of Eastern North America and elsewhere," Mich. Geolog. Survey, 1909. The Monroe Formation.