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THE WASTE AND CONSERVATION OF PLANT FOOD.¹

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ONE of the greatest of the practical problems presented for solution by agricultural chemistry is the conservation of plant food. With an abundance of plant food and a favoring climate, it is difficult to place a limit to the power of the earth for supporting life. We have read much in political economy of the limit of subsistence, and one bold philosopher has based a theory of the limitation of the number of human beings upon the earth on the insufficiency of the earth to support a greater number. Happily, however, the Malthusian philosophy was promulgated before the days of that great agricultural renaissance which has been brought about chiefly through the efforts of experimental agricultural chemistry. I am not so blinded by the achievements of agricultural chemistry as to deny to many other branches of science an important and, in many cases, necessary influence in this development of agricultural science; but I think every candid man will admit that in this development chemistry has always taken the front rank and led the way. This is pre-eminently true of the investigations into the nature and extent of the plant food available on the surface of the earth. In this country, owing to the great stores of wealth which the past had accumulated in the soil, it is only within recent years that the question of the supply of plant food has assumed any practical importance. As long as there

¹ Retiring address of the President of the American Chemical Society, Baltimore Meeting, December 27, 1893.

were virgin fields at the disposal of the agricultural rapist, the conservation and restoration of exhausted fields was of little consequence. The result has been that the wealth of hundreds or, perhaps, thousands of years slowly stored in the soil has been poured forth in a century, not only for the enrichment of this country, but for the benefit of all countries. Unfortunately, or fortunately, these stores are now practically explored and there is little left in this land of virgin fertility to tempt the farmer to new conquests. Not only have these stores of plant food been utilized, but, much to the discredit of the American farmer, they have been wasted. The mark of good agriculture is to see fields yielding annually good returns and increasing, or at least not lessening in fertility. This being true, the history of American agriculture to within a few years must be the history of bad farming, for everywhere we have seen fertile fields losing their fertility and farms once productive abandoned. No difference how great the store may be, if it be continually drawn upon and never replenished, the day will some time come when it will be exhausted. This day has come to a large portion of the agricultural lands of this country and to-day there is an awakening everywhere in regard to the best methods of checking the waste and of restoring what has been lost.

I desire for a brief period, on this occasion, to call the attention of the chemists of this country to some of the methods by which plant food is removed from the fields and some of the direct and indirect ways in which it is and may be returned. On a former occasion¹ I have discussed the extent to which plant food is removed from the soil directly in the crops and the dangers which arise to an agricultural community which continually exports its agricultural products. On that occasion I pointed out the amount of potash, phosphoric acid, and nitrogen per acre annually removed by the crops of the United States, and showed that the only safe agricultural products to send out of a country were sugar, oil, and cotton. It is true that with native, unexhausted soils a country may acquire great wealth by agricultural exports, but the history of the world shows that a

¹ Vice Presidential Address before the American Association for the Advancement of Science, Buffalo, 1886.

country which depends for its wealth and its commerce on agricultural exportation is in the end reduced to pauperism. A single example may serve to accentuate this remark; I refer to the island of Cypress, which two thousand years ago was the granary of many cities bordering on the Mediterranean Sea. Supplying hundreds of thousands of people with corn, it gradually became impoverished, and to-day its soils are perhaps the poorest of any known.

The waste to which I desire to call your attention to-day is not that which normally takes place in the production of a crop, but that which is incidental to the cultivation of the soil and to a certain extent unavoidable. My purpose is to develop, if it be possible, the relations of agricultural chemistry to this waste, with the purpose of pointing out a course by which it can be returned and in what way we may at least reduce to a minimum the unavoidable removal of valuable plant food. You have all, perhaps, surmised the character of this waste; I refer to the denudation of fields by water and to the removal of soluble plant food by the percolation of water through the soil.

The losses due to the denudation of fields are purely of a mechanical character. The natural forest, or the natural covering of grass over an area of soil, prevents, to a large extent, the denudation due to heavy downpours of rain. The removal of the forest, and the destruction of the grass by cultivation, leave the soil in a condition in which it is unable to resist the action of flowing surface water. The muddy character of the water in all streams bordering on cultivated hilly fields after a heavy rain storm is a familiar instance of the tremendous energies which are exerted by a heavy downpour of rain in the carrying of the soil into the streams and its transportation towards the sea.

It is not necessary to emphasize the fact that the agricultural chemist is practically powerless to prevent the surface erosion due to heavy rains, but a few practical lessons derived from the application of chemical discoveries to the soils show how, in a certain measure, even surface erosion may be controlled, or at least reduced to a minimum by the application of the principles

of culture founded upon the facts disclosed by advanced science.

The observing agriculturist will have noticed that even in a hilly country a soil *in situ* underlaid by limestone is less likely to be cut up by gullies than a soil similarly situated and deficient in carbonate of lime. The reason of this is plain. In a soil deficient in lime the clays when once brought into suspension by moving water assume a semi-colloid state and remain indefinitely in suspension. Clays, on the other hand, which are heavily impregnated with lime salts are in a flocculated state, and the larger aggregates thus produced settle quickly. The result of this is that such a soil is less easily moved by water, and a field thus treated less exposed to washing by heavy rains.

Our knowledge of flocculation and its physical and chemical results is due largely to the investigations of Shulze, Schloesing, and Hilgard, and the results of their researches have shown in a most emphatic way the beneficial changes which take place especially in stiff clay soils, by the application of lime.

It is thus an incontrovertible fact that the surface washing of cultivated fields, especially if they be naturally deficient in lime, could be greatly diminished and has been greatly diminished by the free application of this substance.

The change in the physical condition of the soil, which is produced by the lime, is also another important factor worthy of consideration. A stiff clay soil is almost impervious to the penetration of surface water and thus the amount which is carried off is raised to a maximum. A well limed soil, on the contrary, in which the particles are perfectly flocculated, is much more pervious and the amount of water which will be retained and delivered gradually to vegetable growth is much greater. Thus the beneficial effects of lime are manifested in both ways; in the better retention of the flocculated clays and in increasing the capacity of the soil for holding a given amount of water in its interstitial spaces.

There are many other salts which also have the same properties as those of lime, but I have spoken of lime salts chiefly because they are cheaper and, therefore, more economically applied. Perhaps next to lime, common salt would be the most

efficient in producing the results already described; but common salt being extremely soluble would soon be leached out of a soil. On the other hand, lime, even when supplied as hydrate, in which case it is somewhat soluble, quickly becomes converted into a carbonate which is practically insoluble in water which does not contain an excess of carbon dioxide.

I am aware of the fact that liming to prevent erosion by surface drainage has not been emphasized as an example of the benefit of the proper chemical treatment of soils, yet I feel sure that all who will give the subject a thoughtful consideration will agree with me in saying that this aspect of the subject is one of no small importance, especially when considered in respect of hilly fields, and even of fields of more level surface.

Without dwelling long upon this point, it is only necessary to call your attention to the immense quantities of soil material annually conveyed to the sea by the causes of erosion already mentioned to show what an active and powerful foe the farmer has in this source of loss. Anyone who watches, even for a short time, the volume of water carried by the Mississippi into the Gulf of Mexico will have a most effective object lesson in regard to this source of loss.

A more striking lesson may be seen in the hill regions bordering both banks of the Ohio river. Hundreds of fields once covered with sturdy forests of oak, maple, and walnut, and afterwards bearing large crops of maize, tobacco, and wheat, may now be seen furrowed with gullies, as with the wrinkles of age, and abandoned to brush and briers. The same is doubtless true of other hill regions, but I speak the more advisedly of those which have come under my personal observation.

Great, however, as the mechanical loss of plant food is, it is by no means as dangerous as the loss of the soluble materials caused by the percolation of the water through the soil. The study of the nature of the loss of these soluble materials, together with the estimation of their amount, forms the subject of lysimetry. Agricultural chemists have used many devices for the purpose of determining the character and amount of the natural drainage of soils. Evidently the treatment of a specially prepared portion of soil by any solvent, although giving in-

teresting results, does not indicate the natural course of solution. The only way in which this can be determined is to be able to collect, measure and study the character of the drainage from a given portion of the arable surface of the earth *in situ* and under normal conditions. Various methods of lysimetric investigation have been proposed and used, all of them possessing many points of value.

An excellent system of such observation has been established, for instance, at the Agricultural Experiment Station of Indiana. It is not my purpose, however, to discuss the mechanical details of lysimetry, but only to call your attention to the main principles which underlie it. The movement of water near the earth's surface is a matter of especial interest to agriculturists. Whitney¹ has clearly pointed out that the little excess or deficiency of water is of far more importance to the growing crop than the quantity of the excess or deficiency of its other foods. Soils richest in plant food will produce a small harvest if there be a great excess or deficiency of water, while soils which are poor in plant food will produce an abundant crop if the water be present in proper amounts and have proper and timely access to the rootlets of the plant. The study, therefore, of the water movement in the soil, whether laterally, upward, or downward, is of the utmost practical importance. The methods of a study of this kind have been well established by King.

The plant food of the soil, it is well understood, only has access to the absorbent organs of the plant when presented in a proper soluble or semi-soluble form in connection with water. From a chemical standpoint, in connection with the subject under discussion, the movement of water in the soil should be considered in connection, not alone with its power of dissolving plant foods, but with especial reference to its power of carrying them not only away from the reach of the roots of the plant, but even out of the field and into the streams and rivers and eventually into the sea. For our present purpose, therefore, we have only need to examine lysimetric observations for the

¹ "Some Physical Properties of Soils," U. S. Weather Bureau, Bulletin No. 4.

² Ninth Annual Report of the Wisconsin Experiment Station, p. 129, *et seq.*

purpose of determining the kinds of plant food which are most exposed to waste. It is not my purpose to take your time here with a vast array of figures, but I desire only to call your attention to the fact that of the chief plant foods, potash and the nitrates are the ones which are most exposed to loss.

The earliest systematic investigations of the quantity and composition of drainage were commenced at the Rothamsted Station by Lawes and Gilbert¹, in 1870. Lysimeters were constructed for the collection of the drainage water from thirty, forty, and sixty inches depth of soil, respectively, the soil and subsoil being kept in the natural state of aggregation.

Lawes and Gilbert call attention to the fact that, probably, at the Rothamsted Station, not more than five pounds of nitrogen are secured per acre each year from the atmosphere and the rain-water, while the average loss of nitrogen through the drainage water is over thirty pounds per acre. The quantity, of course, varies with the amount of rain-fall and the activity of nitrification. They speak of the possible exaggeration of the loss of nitrogen on account of the fact that the air had access to the soil both from below and above and therefore the process of nitrification where the lysimeters were placed might have been intensified.

Among the latest researches on this subject are those of Deherain.² It is pointed out by this author that the character of the crop grown upon the cultivated field has much to do with the determination of the loss of nitrogen per acre. Those crops which require an immense amount of moisture for their growth, such as the sugar beet, would tend thereby to prevent the loss of nitrogen in the drainage waters, the nitrates being stored in the beet instead of being given up to percolation. In general, it may be said that it is the quantity of the drainage water rather than its richness in nitrates which determines the total loss due to percolation, and from this it may be inferred that the loss by drainage is directly proportional to the rain-fall and inversely proportional to the magnitude of the harvest. The season at which the greatest loss takes place is also, there-

¹ *Jour. Roy. Agric. Soc.*, 17, 241-79 and 311-50; 16, 1-71.

² *Annales Agronomiques*, February 25, 1893, pp 65, et seq.

fore, the one in which the growth of the plant is the least vigorous, provided that the vigor of nitrification and quantity of rain-fall remain the same. When plants grow vigorously and when they occupy the soil for a long time, the losses due to drainage are reduced to a minimum. On the other hand, with plants which rapidly ripen, so that the harvest follows soon after the sowing, the losses are greater. The farmer, therefore, who suffers a failure of his crop, not only loses from the smallness of the harvest, but also by the percolation of the water through the soil. For this reason, it is obvious that leaving fields fallow is a very dangerous proceeding. Deherain found that fallow fields during the season lost as high as fifty kilograms of nitrogen per hectare, corresponding to 330 kilograms of nitrate of soda, worth seventy-six francs. These figures show plainly the magnitude of the losses which take place in the one item of nitrogen alone, due to the percolation of rain-water through the soil.

In this connection it may be of interest again to refer to the favorable action of lime in a great many soils in regard to its power of increasing the ability of a soil to hold the soluble plant foods against their removal by water. This favorable action is particularly manifested in many soils in the power of lime to increase their capacity for holding potash.

Warington explains this action of the lime salts, especially the carbonate, by suggesting that by combining with the acids of certain salts, as the carbonates, sulphates, chlorides, and nitrates, they allow the bases of these salts to unite with the hydrated metallic oxides. The carbonate of lime also converts the soluble acid phosphates, applied in manure, to the sparingly soluble calcium phosphates, which, as they gradually enter into solution are converted into ferric and aluminic phosphates. An admirable description of the absorptive power of soils has been given by Warington¹ and many other authors have also discussed this matter in detail.

We can see from the data given above how water continually acts upon a soil in the removal of certain soluble plant foods. It might be inferred from this that all arable soils exposed con-

¹ Practice with Science, 2.

tinually to rains would soon be exhausted of all valuable, soluble plant food. But it has also been pointed out how certain constituents of the soil have a faculty of absorbing and retaining materials which are soluble in water under ordinary conditions. It must not be forgotten also that the rain-water which descends upon the earth is not pure. Rain-water brings to the earth a certain amount of valuable plant food. Not only does it absorb and hold in solution ammonia and nitric acid, which may be formed by the electrical discharges in the air, but it also collects and brings to the surface of the earth vast quantities of meteoric dust containing valuable fertilizing principles. Thus we have constantly entering the soil water which contains more or less of the materials necessary to plant growth. Even the drainage waters, which leave an arable field, may not reach the sea without giving up much of this material. The drainage waters in passing underneath the earth's surface take devious courses and are often brought near to the surface again or are poured upon soils which are quite different in their texture from those furnishing the materials in solution. Sterry Hunt¹ has pointed out how such waters sooner or later come upon permeable strata by which they are absorbed and in their subterranean circulation undergo important changes. Especially when these waters reach argillaceous strata their content of neutral, soluble salts may suffer great changes. Such waters charged with organic and mineral materials contain usually large amounts of potassium salts and notable quantities of silica and phosphates, and in many cases ammoniated salts, and nitrites or nitrates.

The experiments of Way, Voelcker, and others have shown that in contact with argillaceous sediments these waters give up their potash, ammonia, silica, phosphoric acid and organic matter, which remain in combination with the soil; on the other hand, soda, magnesia, sulphuric acid and chlorine are not removed from the drainage waters. Eichorn attributes this power of selective absorption in the soil chiefly to the action of hydrated double aluminum silicates, and supposes that the process is one of double exchange, equivalents of lime or soda being given up for the potash retained. By this power of

¹ "Chemical and Geological Essays," 95.

selective absorption the mineral matters required for the growth of plants tend to be retained in most soils, while those not required for the growth of plants are removed. Nevertheless, much of the valuable mineral material in solution must escape absorption and finally find its way into the streams, rivers, and seas.

From the foregoing summary of the methods of waste of plant food it has been seen that in spite of all the precautions of the farmer and the chemist, and in spite of the selective absorption of the soil, immense quantities of valuable plant food are carried into the sea, where apparently they are lost to agriculture forever. But this is only an apparent loss. The economies of nature are so happily adjusted as to provide a means of gradually returning in some form or other to the power of the farmer the plant food which has been apparently destroyed. It is true that this return will probably not be to the locality where the waste originally occurred, and it may not take place until after the lapse of thousands of years, but this is of no consequence. Provided arable lands in general receive in some way and at some time a certain return for the plant food removed, it is entirely immaterial whether this be the original plant food removed or other equally as good.

The sea is the great sorting ground into which all this waste material is poured. The roller processes of nature, like the mills of the gods, grind exceedingly slow and small, and the sea becomes the bolting cloth by which the products of milling are separated and sorted out. As soon as this waste material is poured into the sea, the process of sorting at once begins. The carbonate of lime becomes deposited in vast layers, or by organic life is transformed into immense coral formations or into shells. Phosphoric acid is likewise sifted out into phosphatic deposits or passes into the organic life of the sea. Even the potash, soluble as it is, becomes collected into mineral aggregates or passes into animal or vegetable growth. All these valuable materials are thus conserved and put into a shape in which they may be returned sooner or later, to the use of man. In the great cosmic economy there is no such thing as escape from usefulness of any valuable material.

Sterry Hunt¹ has called especial attention to this sifting and sorting power of water and the important part it plays in the formation of crystalline rocks. "Igneous fusion," he says, "destroys the mineral species of the crystalline and brings them back as nearly as possible to the great primary and undifferentiated material. This is the great destroyer and disorganizer of mineral as well as of organic matter. Subterranean heat in our time acting on buried aqueous sediments destroys carbonates, sulphates, and chlorides, with the evolution of acidic gases and the generation of basic silicates and thus repeats in miniature the conditions of the anteneptunian chaos.

"On the other hand each mass of cooling igneous rock in contact of water begins anew the formative process. The hydrated amorphous product palagonite, is, if we may be allowed the expression, a sort of silicated protoplasm and by its differentiation yields to the solvent action of water, the crystalline silicates which are the constituent elements of the crenitic rocks, leaving at the same time a more basic residuum abounding in magnesia and iron oxide and soluble not by crenitic but sub-aerial action."

Let me call attention, for a few moments, to some of the more important ways, pointed out through the researches of agricultural chemists, in which these waste products are restored. We are inclined to look upon the sea as devoid of vegetable growth, but the gardens of the sea are no less fully stocked with economic plants than the gardens of the land. The sea-weeds of all genera and species are constantly separating valuable materials from the waters of the ocean and placing them again in organic form. Many years ago Forchhammer² pointed out the agricultural value of certain fucoids. Many chemists have contributed important data in regard to the composition of these bodies. Jenkins³ gives analyses of several varieties of sea-weed, showing that in the green state it is quite equal to stall manure. The farmers are said to pay as high as five cents a bushel for it. Goessmann⁴ also gives analyses of several varieties of sea-weed.

¹ *Mineral Physiology and Physiography*, 188.

² *J. prakt. Chem.*, 1st Series, 38, 388.

³ Annual Report, Conn. State Exp't. Sta., 1890, 72.

⁴ Annual Report, Mass. State Exp't. Sta., 1887, 223.

We are indebted, however, to the reports of Wheeler and Hartwell¹ for the fullest and most systematic discussion of the agricultural value of sea-weeds which has been published. Their interesting and elaborate report was published in January, 1893. Those who are interested in the details of this work can find all known publications on the subject properly arranged, classified, and studied in the publication mentioned. We learn from this publication that sea-weed was used as a fertilizer as early as the fourth century, and its importance for this purpose has been recognized more and more in modern days, especially since chemical investigations have shown the great value of the food materials contained therein.

To show the commercial importance of sea-weed as a fertilizer, it is only necessary to call attention to the fact that in 1885 its value for use as fertilizer in the State of Rhode Island was \$65,044, while the value of all other commercial fertilizers was only \$164,133. While sea-weed, in a sense, can only be successfully applied to littoral agriculture, yet the extent of agricultural lands bordering on the sea is so great as to render the commercial importance of the matter of the highest degree of interest.

It is not my intention here to enter into the discussion of the methods of preparing the sea-weed, the times at which it should be gathered and the best means of applying it to the soil; these matters are all thoroughly discussed by Wheeler and Hartwell in the publication mentioned. As an instance of the value of sea-weed at a point far removed from the Rhode Island coast, I may be permitted to say that near the mouth of the Caloosahatchee river, at the town of Ft. Meyers. I saw the most happy effects produced in intensive culture by the application of sea-weed alone to the sandy soils bordering on this arm of the sea. Dr. Washburn, of the Florida Experiment Station, was conducting the experiments to which I refer and he spoke in the highest terms of the value of the sea-weed in his work. Thousands of tons of this sea-weed are allowed to go to waste annually along these shores, simply because the agriculturist has not been informed in regard to its fertilizing value.

There are many other uses for sea-weed besides the agricul-

¹ Rhode Island Exp't. Sta. Bull. 21

tural one but in these we are not much interested, except incidentally. Many of the varieties of sea-grass are used for filling mattresses, cushions, etc. Other varieties are burned and their ashes used for the manufacture of soda, iodine, and bromine. The gelatinous portions of sea-weeds become exceedingly hard and elastic upon being dried and have been moulded into various forms as substitutes for horn and shells in making handles for knives, files, and other tools. In the Techno-Chemical receipt book, on page 177, may be found receipts for making artificial ebony from the charcoal obtained from sea-weeds; also for making leather, soap, and glue. For the latter purpose the plants are dried and powdered, extracted with warm water, with or without the addition of alcohol. The solution is allowed to settle at a temperature of 120° F. When cool it forms a jelly which is used for various purposes. The direction is then given for making transparent sea-weed leather, opaque sea-weed leather, sea-weed soap, and sea-weed glue.

No attempt can be made to give the quantities of sea-weed which are annually cast upon the shores of the different continents. Perhaps Rhode Island is no more favored in this respect than any other locality and we have seen the value of the sea-weed which was gathered for agricultural purposes in that State alone. The amount gathered represents only a very small fraction of the amount which was thrown upon the shores. It is easy, therefore, to conclude that the quantities of nitrogen, phosphoric acids and potash annually removed from the seas by the plants living therein are no less great in magnitude than those removed from the land by crops and plants of all kinds.

But sea-weed and other vegetable products of the sea are not the only vehicles in which the plant food in solution in the waters of the ocean may be returned to the uses of man. The animal life of the ocean is not less important than that of the land. In the animal economy of the ocean are gathered, therefore, immense quantities of valuable food material which are thus placed in a condition to be at least in part restored in the form of food. Relatively, phosphoric acid and nitrogen are restored in much greater quantities than potash. The composition of fish in general shows that relatively larger quantities of

phosphoric acid and nitrogen are found than of fat and potash. The chemical composition of the nutritive portion of fishes has been thoroughly investigated by Atwater.

The percentage of phosphoric acid in the flesh of American fishes, in its fresh state, is about one-half of one per cent. In one instance, that of smelt, Atwater found, 0.81 per cent. in the flesh of the fish. In the water-free substance of the flesh the percentage of phosphoric acid in round numbers is 2.5. In the case of the smelt above mentioned it amounted to 5.49 per cent. When it is considered that the bones and other refuse of the fish presumably richer in phosphoric acid than the flesh, were not included in this investigation, the quantity of phosphoric acid in fish is distinctly brought to view.

The quantity of albuminoids in the water-free substance of the flesh of fish is enormously high as compared with that of ordinary foods. In round numbers it may be said to be about 75 per cent. of the total water-free substance. In some cases the albuminous matter, or in other words the protein, makes up almost the whole of the water-free substance as in the case of a brook trout, quoted by Atwater, in which the percentage of protein in the dry flesh was 93.25; and of a perch in which it was 93.33; and of a sea bass in which it was 95.88; and a red snapper in which it was 95.38, and others in which even a higher percentage was reported.

It is thus seen that the ordinary fishes of the ocean collect, especially the two great elements of plant food, phosphorus, and nitrogen.

Oysters and other shell fishes collect not only large quantities of phosphorus and nitrogen, but also larger quantities of carbonate of lime. As has been intimated in another place, it is entirely probable that in earlier times when the sea was richer in phosphoric acid than at present, considerable quantities of phosphate of lime may have been secreted with the carbonate of lime in the shell. At the present time, however, the phosphate of lime has almost or quite disappeared from the matters of which shells are composed.

¹ The Chemical Composition and Nutritive Values of Food Fish and Aquatic Vertebrates, by W. O. Atwater. Report of the U. S. Commissioner of Fish and Fisheries, 1888, 679-868.

While the art of fishing is practiced chiefly for the purpose of gaining human food, yet in many large fishing districts the fish waste becomes valuable fertilizing material. Some kinds of fish, as the menhaden, are, however, collected chiefly for their fertilizing value. The use of fish for fertilizing purposes is not new. A most interesting description of the use of agricultural fertilizers by the American Indians is given by Goode.¹ As long ago as 1875 the value of the nitrogen derived from the menhaden was estimated to be about two million dollars. In the year 1878 it is estimated that 200,000 tons of menhaden fish were captured between Cape Henry and the Bay of Fundy. The oil is first extracted from the fish for commercial purposes and afterward the residue is dried and ground and sold to farmers and fertilizer manufacturers. For a complete history of the menhaden the articles of Prof. G. Brown Goode, in the report of the U. S. Commissioner of Fish and Fisheries for 1877 and 1879, may be consulted.

The honor of teaching the American colonists the use of artificial fertilizers belongs, without doubt, to an Indian named Squanto. In Governor Bradford's "History of Plimouth Plantation" is given an account of the early agricultural experiences of the Plymouth colonists. In April, 1621, at the close of the first long dreary winter "they (as many as were able) began to plant their corne, in which service Squanto (an Indian) stood them in great stead, showing them both ye manner how to set it, and after how to dress and tend it. Also he tould them, axcepte they got fish and set with it (in these old grounds) it would come to nothing; and he showed them yt in ye middle of Aprili, they should have store enough come up ye brooke by which they begane to build and taught them how to take it."²

Another account mentioned by Goode of the practice of the Indians in this respect may be found in George Mourt's "Relation or Journal of the Beginning and Proceedings of the English Plantation settled at Plimouth in New England, by certain English Adventurers, both merchants and others, London, 1622." "We set the last spring some twenty acres of Indian corn, and

¹ *American Naturalist*, 14, July, 1880, No. 7., 473, *et seq.*

² *Coll. Mass. Hist. Soc.*, 4th Series, 3, 100, 1856.

sowed some six acres of barley and pease, and, according to the manner of the Indians, we manured our ground with herrings, or rather shads, which we have in great abundance and take with great ease at our doors. Our corn did prove well, and God be praised, we had a good increase of Indian corn, and our barley indifferent good."¹

Thomas Morton, in his "New England Canaan," London, 1632, wrote of Virginia: "There is a fish (by some called shadds, by some, allizes,) that at the spring of the yeare passe up the rivers to spawn in the pond, and are taken in such multitudes in every river that hath a pond at the end that the inhabitants doung their ground with them. You may see in one towne a hundred acres together, set with these fish, every acre taking 1,000 of them, and an acre thus dressed will produce and yield so much corn as three acres without fish; and (least any Virginea man would infere hereupon that the ground of New England was barren, because they use more fish in setting their corne, I desire them to be remembered, the cause is plaine in Virginea) they have it not to sett. But this practice is onely for the Indian maize (which must be set by hands), not for English grain; and this is, therefore, a commodity there.

The following amusing study quoted by Goode is taken from the records of the town of Ipswich, May 11, 1644.

"It is ordered that all the doggs for the space of three weeks from the publishing hereof, shall have one legg tyed up, and if such a dog shall break loose and be found doing harm the owner of the dogg shall pay damage. If a man refuse to tye up his dogg's legg, and hee bee found scraping up fish in a cornfield, the owner thereof shall pay twelve pence damage beside whatever damage the dogg doth. But if any fish their house lotts and receive damage by doggs, the owners of these house lotts shall bear the damage themselves."

The practice of using fish, therefore, for fertilizing purposes, is many centuries old, but until recent years the farmers residing along the coast were the only ones who received any benefit therefrom; but since the more careful scientific study of the value of fish fertilization, the nitrogenous elements taken from

¹ Coll. Mass. Hist. Soc., 2nd Series, 9, 175, 196.

the sea by the fish now find their way not only to the gardens and truck farms along the New England and New Jersey coasts but also to the wheat fields of Ohio and the cotton fields of North Carolina.

Conservation of Nitrogen.—Attention has been called to the manner in which the nitrogen carried into the ocean by the waste of the land is returned in great part through the marine, vegetable, and animal life. Immense quantities of waste nitrogen, however, are further secured, both from sea and land, by the various genera of birds. The well-known habits of birds in congregating in rookeries during the nights, and at certain seasons of the year tends to bring into a common receptacle the nitrogenous matters which they have gathered and which are deposited in their excrement and in the decay of their bodies. The feathers of birds are particularly rich in nitrogen, and the nitrogenous content of the flesh of fowls is also high. The decay therefore, of remains of birds, especially if it take place largely excluded from the leaching of water, tends to accumulate vast deposits of nitrogenous matter. If the conditions in such deposits are favorable to the processes of nitrification, the whole of the nitrogen, or at least the larger part of it, which has been collected in this débris, becomes finally converted into nitric acid and is found combined with appropriate bases as deposits of nitrates. The nitrates of the guano deposits and of the deposits in caves arise in this way. If these deposits are subject to moderate leaching the nitrate may become infiltrated into the surrounding soil, making it very rich in this form of nitrogen. The beds and surrounding soils of caves are often found highly impregnated with nitrates.

While for our purpose, deposits of nitrates only are to be considered which are of sufficient value to bear transportation, yet much interest attaches to the formation of nitrates in the soil even when they are not of commercial importance.

In many soils of tropical regions not subject to heavy rainfalls, the accumulation of these nitrates is very great. Müntz and Marcano¹ have investigated many of these soils to which attention was called first by Humboldt and Boussingault.

¹ *Compt. rend.*, 101, 1885, 65, et seq.

They state that these soils are incomparably more rich in nitrates than the most fertile soils of Europe. The samples which they examined were collected from different parts of Venezuela and from the valleys of the Orinoco as well as on the shore of the Sea of Antilles. The nitrated soils are very abundant in this region of South America where they cover large surfaces. Their composition is variable, but in all of them carbonate and phosphate of lime are met with and organic nitrogenous material. The nitric acid is found always combined with lime. In some of the soils as high as thirty per cent. of nitrate of lime have been found. Nitrification of organic material takes place very rapidly the year round in this tropical region. These nitrated soils are everywhere abundant around caves, as described by Humboldt, caves which serve as the refuge of birds and bats. The nitrogenous matters, which come from the decay of the remains of these animals, form true deposits of guano which are gradually spread around, and which, in contact with the limestone and with access of air, suffer complete nitrification with the fixation of the nitric acid by the lime.

Large quantities of this guano are also due to the débris of insects, fragments of elytra, scales of the wings of butterflies, etc., which are brought together in those places by the millions of cubic meters. The nitrification, which takes place in these deposits, has been found to extend its products to a distance of several kilometers through the soil. In some places the quantity of the nitrate of lime is so great in the soils that they are converted into a plastic paste by this deliquescent salt.

It is suggested by the authors that the co-existence of the nitrate and phosphate of lime is sufficient in all cases to demonstrate the organic origin of the nitric acid. It would not be possible to attribute such an origin to the nitrate present in these soils if it could not be determined that it was thus associated with phosphate and other remains, the last witnesses of a former animal life.

As a result of the observations of Müntz and Marcano, they conclude that it is not proper to accredit to the electrical discharges in the atmosphere the origin of the nitric acid forming

these deposits although they admit primarily the source of the nitric acid may have been due to electricity, but that it first was passed through the organism of the plant and thence into that of the animal whence it is accumulated in the deposits referred to.

The theory of Müntz and Marcano in regard to the nitrates of soils, especially in the neighborhood of caves, is probably a correct one, but there are many objections to accepting it to explain the great deposits of nitrate of soda which occur in many parts of Chile. Another point, which must be considered also, is this: That the processes of nitrification can not now be considered as going on with the same vigor as formerly. Some moisture is necessary to nitrification, as the nitrifying ferment does not act in perfectly dry soil, and in many localities in Chile where the nitrates are found it is too dry to suppose that any active nitrification could now take place.

The existence of these nitrate deposits has long been known. The old Indian laws originally prohibited the collection of the salt, but nevertheless it was secretly collected and sold. Up to the year 1821, soda saltpeter was not known in Europe except as a laboratory product. About this time the naturalist, Mariano de Rivero, found on the Pacific coast, in the Province of Tarapacá, immense new deposits of the salt. Later the salt was found in equal abundance in the Territory of Antofogasta and further to the south in the desert of Atacama, which forms the Department of Taltal.

At the present time the collection and export of saltpeter from Chile is a business of great importance. The largest export which has ever taken place in one year was in 1890, when the amount exported was 927,290,430 kilograms; of this quantity 642,506,985 kilograms were sent to England and 86,124,870 kilograms to the United States. Since that time the imports of this salt into the United States have largely increased.

According to Pissis¹ these deposits are of very ancient origin. This geologist is of the opinion that the nitrate deposits are the result of the decomposition of feldspathic rocks; the bases thus

¹ A most interesting article on the subject may be found in *Jour. Roy. Agric. Soc.*, 1852, 13, 349, et seq.

² Fuchs and De Launy, *Traité des Gîtes Minéraux*, 1893, 1, 425.

produced gradually becoming united with the nitric acid provided from the air.

According to the theory of Nöllner¹ the deposits are of more modern origin and due to the decomposition of marine vegetation. Continuous solution of soils beneath the sea gives rise to the formation of great lakes of saturated water, in which occurs the development of much marine vegetation. On the evaporation of this water, due to geologic isolation, the decomposition of nitrogenous organic matter causes generation of nitric acid, which, coming in contact with the calcareous rocks, attacks them, forming nitrate of calcium, which, in presence of sulphate of sodium, gives rise to a double decomposition into nitrate of soda and sulphate of calcium.

The fact that iodine is found in greater or less quantity in Chile saltpeter is one of the chief supports of this hypothesis of marine origin, inasmuch as iodine is always found in sea plants and not in terrestrial plants. Further than this, it must be taken into consideration that these deposits of nitrate of soda contain neither shells nor fossils, nor do they contain any phosphate of lime. The theory, therefore, that they were due to animal origin is scarcely tenable.

Lately extensive nitrate deposits have been discovered in the U. S. of Columbia.² These deposits have been found extending over thirty square miles and vary in thickness from one to ten feet. The visible supply is estimated at 7,372,800,000 tons, containing from 1.0 to 13.5 per cent. of nitrate. The deposits consist of a mixture of nitrate of soda, chloride of soda and sulphate of calcium, sulphate of alumina, and insoluble silica. It is thought that the amount of these deposits will almost equal those in Chile and Peru.

Phosphatic Deposits.—Gautier³ calls attention to the fact that the oldest phosphates are met with in the igneous rocks, such as basalt, trachyte, etc., and even in granite and gneiss. It is from these inorganic sources, therefore, that all phosphatic plant food must have been drawn. In the second order in age

¹ El Salitre de Chile, René F. Le Feuvre y Arturo Dagino, 1893, 12.

² Bureau of American Republics, *Monthly Bulletin*, December, 1893, 18, et seq.

³ *Compt. rend.*, 116, 1271, 6.

Gautier places the phosphates of hydro-mineral origin. This class not only embraces the crystalline apatites but also those phosphates of later formation, formed from hot mineral waters in the jurassic, cretaceous, and tertiary deposits.

These deposits are not directly suited to nourish plants.

The third group of phosphates in order of age and assimilability embraces the true phosphorites containing generally some organic matter. They are all of organic origin. In caves where animal remains are deposited there is an accumulation of nitrates and phosphates.

Not only do the bones of animals furnish phosphates, but they are also formed in considerable quantities by the decomposition of substituted glycerides such as lecithin.

The ammonia produced by the nitrification of the albuminoid bodies combines with the free phosphoric acid thus produced, forming ammonium or diammonium phosphates.

The presence of ammonium phosphates in guanos was first noticed by Chevreul more than half a century ago.

If such deposits overlay a pervious stratum of calcium carbonate, such as chalk, and are subject to leaching, a double decomposition takes place as the lye percolates through the chalk. Acid calcium phosphate and ammonium carbonate are produced. By further nitrification the latter becomes finally converted into calcium nitrate. In like manner aluminium phosphates are formed by the action of decomposing organic matter on clay.

Davidson¹ explains the origin of the Florida phosphates by suggesting that they arose chiefly through the influx of animals driven southward by the glacial period. According to his supposition the waters of the ocean, during the cenozoic period contained more phosphorus than at the present time. The waters of the ocean over Florida were shallow and the shell fish existing therein may have secreted phosphate as well as carbonate of lime. This supposition is supported by an analysis of a shell of *lingula ovalis*, quoted by Dana, in which there were 85.79 per cent. of lime phosphate. In these waters were also many fishes of all kinds and their débris served to increase the

¹ *Engineering and Mining Journal*, quoted in the "Phosphates of America," by Wyatt, 66. *et seq.*

amount of this substance. As the land emerged from the sea came the great glacial epoch driving all terrestrial animals southward. There was therefore a great mammal horde in the swamps and estuaries of Florida. The bones of these animals contributed largely to the phosphatic deposits. In addition to this, the shallow sea contained innumerable sharks, manatees, whales and other inhabitants of tropical waters, and the remains of these animals added to the phosphatic store.

While these changes were taking place in the quaternary period, the Florida peninsula was gradually rising and as soon as it reached a considerable height, the process of denudation by the action of water commenced. Then there was a subsidence and the peninsula again passed under the sea and was covered with successive layers of sand. The limestones during this process, had been leached by rain-water containing an excess of carbonic acid. In this way the limestones were gradually dissolved while the insoluble phosphate of lime was left in suspension. During this time the bones of the animals before mentioned by their decomposition added to the phosphate of lime present in the under lying strata, while some were transformed into fossils of phosphate of lime just as they are found to-day in vast quantities.

Wyatt¹ explains the phosphate deposits somewhat differently. According to him, during the miocene submergence there was deposited upon the upper eocene limestones, more especially in the cracks and fissures resulting from their drying up, a soft, finely disintegrated calcareous sediment or mud. The estuaries formed during this period were swarming with animal and vegetable life, and from this organic life the phosphates were formed by decomposition and metamorphism due to the gases and acids with which the waters were charged.

After the disappearance of the miocene sea there were great disturbances of the strata. Then followed the pliocene and tertiary periods and quaternary seas with their deposits and drifts of shells, sands, clays, marls, bowlders and other transported materials, supervening in an era when there were great fluctuations of cold and heat.

¹ *Engineering and Mining Journal*, August 23, 1890.

By reason of these disturbances the masses of the phosphate deposits which had been infiltrated in the limestones became broken up and mingled with the other débris and were thus deposited in various mounds or depressions. The general result of the forces which have been briefly outlined, was the formation of bowlders, phosphatic débris, etc. Wyatt therefore classifies the deposits as follows:

1. Original pockets or cavities in the limestone filled with hard and soft rock phosphates and débris.
2. Mounds or beaches, rolled up on the elevated points, and chiefly consisting of huge bowlders of phosphate rock.
3. Drift or disintegrated rock, covering immense areas, chiefly in Polk and Hillsboro counties, and underlying Peace river and its tributaries.

N. H. Darton, of the U. S. Geological Survey, ascribes the phosphate beds of Florida to the transformation of guano.¹ According to this author two processes of decomposition have taken place; one of these is the more or less complete replacement of the carbonate by the phosphate of lime; the other is a general stalactitic coating of phosphatic material. Darton further calls attention to the relation of the distribution of the phosphate deposits as affecting the theory of their origin, but does not find any peculiar significance in the restriction of these deposits to the western ridge of the Florida peninsula.

As this region evidently constituted a long, narrow peninsula during early miocene times it is a reasonable, tentative hypothesis that during this period guanos were deposited from which was derived the material for the phosphatization of the limestone either at the same time or soon after.

Darton closes his paper by saying that the phosphate deposits in Florida will require careful, detailed geologic exploration before their relations and history will be fully understood.

According to Dr. N. A. Pratt the rock or bowlder phosphate had its immediate origin in animal life and the phosphate bowlder is a true fossil. He supposes the existence of some species in former times in which the shell excreted was chiefly phosphate of lime. The fossil bowlder, therefore,

¹ *Amer. Jour. of Science*, 41, February, 1891.

becomes the remains of a huge foraminifer which had identical composition in its skeleton with true bone deposits or of organic matter.

Perhaps the most complete exposition of the theory of the recovery of waste phosphates, with especial reference to their deposition in Florida, has been given by Eldridge,¹ of the U. S. Geological Survey. Eldridge calls attention to the universal presence of phosphates in sea water and to the probability that in earlier times, as during the miocene and eocene geologic periods, the waters of the ocean contained a great deal more phosphate in solution than at the present time. He cites the observations of Bischof, which show the solubility of different phosphates in waters saturated with carbon dioxide. According to these observations apatite is the most insoluble form of lime phosphate, while artificial basic slag phosphate is the most soluble. Among the very soluble phosphates, however, are the bones of animals, both fresh and old. Burnt bones, however, are more soluble than bones still containing organic matter. Not only are the organic phosphates extremely soluble in water saturated with carbon dioxide but also in water which contains common salt or chloride of ammonium. The presence of large quantities of common salt in sea water would, therefore, tend to increase its power of absorbing lime phosphates of organic origin. It is not at all incredible, therefore, to suppose that at some remote period the waters of the ocean, as indicated by these theories, were much more highly charged with phosphates than at the present time.

According to Eldridge, the formation of the hard rock and soft phosphates may be ascribed to three periods: First, that in which the primary rock was formed; second, that of secondary deposition in the cavities of the primary rock; third, that in which the deposits thus formed were broken up and the resulting fragments and comminuted material were redeposited as they now occur.

The first of these stages began probably not later than the close of the older miocene, and within the eocene area it may

¹ A preliminary sketch of the phosphates of Florida. By Geo. H. Eldridge, author's edition, 1892, 18, et seq.

have begun much earlier. Whether the primary phosphate resulted from a superficial and heavy deposit of soluble guanos, covering the limestones, or from the concentration of phosphate of lime already widely and uniformly distributed throughout the mass of the original rock, or from both, is a difficult question. In any event, the evidence indicates the effect of the percolation of surface-waters, highly charged with carbonic and earth-acids, and thus enabled to carry down into the mass of the limestone dissolved phosphate of lime, to be redeposited under conditions favorable to its separation. Such conditions might have been brought about by the simple interchange of bases between the phosphate and carbonate of lime thus brought together, or by the lowering of the solvent power of the waters through loss of carbonic acid. The latter would happen whenever the acid was required for the solution of additional carbonate of lime, or when, through aeration, it should escape from the water. The zone of phosphate-deposition was evidently one of double concentration, resulting from the removal of the soluble carbonate thus raising the percentage of the less soluble phosphate, and from the acquirement of additional phosphate of lime from the overlying portions of the deposit."

"The thickness of the zone of phosphatization in the eocene area is unknown, but it is doubtful if it was over twenty feet. In the miocene area the depth has been proved from the phosphates *in situ* to have been between six and twelve feet."

The deposits of the secondary origin, according to Eldridge, are due chiefly to sedimentation, although some of them may have been due to precipitation from water. This secondary deposition was kept up for a long period, until stopped by some climatic or geologic change. The deposits of phosphates thus formed in the Florida peninsula are remarkably free from iron and aluminum, in comparison with many of the phosphates of the West Indies.

The third period in the genesis of the hard-rock deposits embraces the period of formation of the original deposits and their transportation and storage as they are found at the present time. The geologic time at which this occurred is somewhat uncertain but it was probably during the last submergence of the peninsula.

In all cases the peculiar formation of the Florida limestone must be considered. This limestone is extremely porous and, therefore, easily penetrated by the waters of percolation. A good illustration of this is seen on the southwestern and southern edges of Lake Okeechobee. In following down a drainage canal which had been cut into the southwest shore of the lake I saw the edge of the basin, which is composed of this porous material. The appearance of the limestone would indicate that large portions of it had already given way to the process of solution. The remaining portions were extremely friable, easily crushed, and much of it could be removed by the ordinary dredging machines. Such a limestone as this is peculiarly suited to the accumulation of phosphatic materials, due to the percolation of the water containing them. The solution of the limestone and consequent deposit of the phosphate of lime is easily understood when the character of this limestone is considered.

Shaler, as quoted by Eldridge in the work already referred to, refers to this characteristic of the limestone and says that the best conditions for the accumulation of valuable deposits of lime phosphate in residual débris appear to occur where the phosphatic lime marls are of a rather soft character; the separate beds having no such solidity as will resist the percolation of water through innumerable incipient joints such as commonly pervade stratified materials, even when they are of a very soft nature.

Eldridge is also of the opinion that the remains of birds are not sufficient to account for the whole of the phosphatic deposits in Florida. He ascribes them to the joint action of the remains of birds, of land and marine animals and to the deposition of the phosphatic materials in the waters in the successive subsidences of the surface below the water line.¹

Potash Deposits.—In the foregoing pages I have tried to set clearly before you the different ways in which the waste of nitrogen and phosphoric acid has been recovered by nature in a form suitable for restoration to arable fields. In the case of potash, however, we have seen that this

¹ For an elaborate discussion of phosphate deposits consult *Géol. Minéraux*, par Fuchs et DeLanuy, 309, et seq.

element is not restored by the processes already mentioned, in amounts proportionate to nitrogen and phosphorus. Potash salts, being extremely soluble, are likely to be held longest in solution. Some of them, of course, are recovered in the animal and vegetable life, of which we have spoken, but the great mass of potash carried into the sea still remains unaccounted for. The recovery of the waste of potash is chiefly secured by the isolation of sea waters containing large quantities of this salt and their subsequent evaporation. Such isolation of sea waters takes place by means of geologic changes in the level of the land and sea. In the raising of an area above the sea level there is almost certain to be an enclosure, of greater or less extent, of the sea water in the form of a lake. This enclosure may be complete or only partial, the enclosed water area being still in communication with the main body of the sea by means of small estuaries. If this body of water be exposed to rapid evaporation, as was doubtless the case in past geologic ages, there will be a continual influx of additional sea water through these estuaries to take the place of that evaporated. The waters may thus become more and more charged with saline constituents. Finally a point is reached in the evaporation when the less soluble of the saline constituents begin to be deposited. In this way the various formations of mineral matter, produced by the drying up of enclosed waters, take place.

The most extensive deposits of potash known are those in the neighborhood of Stassfurt, in Germany. The following description probably represents the method of formation of these deposits:¹

“The Stassfurt salt and potash deposits had their origin thousands of years ago, in a sea or ocean, the waters of which gradually receded, leaving near the coast, lakes which still retained communication with the great ocean by means of small channels. In that part of Europe the climate was still tropical, and the waters of these lakes rapidly evaporated but were constantly replenished through these small channels connecting them with the main body. Decade after decade this continued, until by evaporation and crystallization, the various salts pres-

¹ Potash, Columbian Exposition, German Kali Works, 34.

ent in the sea water were deposited in solid form. The less soluble material, such as sulphate of lime or 'anhydrite,' solidified first and formed the lowest stratum. Then came common rock salt with a slowly thickening layer which ultimately reached 3000 feet, and is estimated to have been 13,000 years in formation. This rock salt deposit is interspersed with lamellar deposits of 'anhydrite,' which gradually diminish towards the top and are finally replaced by the mineral 'polyhalite,' which is composed of sulphate of lime, sulphate of potash, and sulphate of magnesia. The situation in which this polyhalite predominates is called the 'polyhalite region' and after it comes the 'kieserite region,' in which, between the rock salt strata, kieserite (sulphate of magnesia) is imbedded. Above the kieserite lies the 'potash region,' consisting mainly of deposits of carnallite, a mineral compound of muriate of potash and chloride of magnesia. The carnallite deposit is from 50 to 130 feet thick and yields the most important of the crude potash salts and that from which are manufactured most of the concentrated articles, including muriate of potash.'

"Overlying this region is a layer of impervious clay which acts as a water-tight roof to protect and preserve the very soluble potash and magnesia salts, which, had it not been for the very protection of this overlying stratum, would have been long ages ago washed away and lost by the action of the water percolating from above. Above this clay roof is a stratum, of varying thickness of anhydrite, (sulphate of lime,) and still above this a second salt deposit, probably formed under more recent climatic and atmospheric influences or possibly by chemical changes in dissolving and subsequent precipitation. This salt deposit contains ninety-eight per cent. (often more) of pure salt, a degree of purity rarely elsewhere found. Finally, above this are strata of gypsum, tenacious clay, sand, and limestone, which crop out at the surface."

"The perpendicular distance from the lowest to the upper surface of the Stassfurt salt deposits is about 5000 feet (a little less than a mile), while the horizontal extent of the bed is from the Harz Mountains to the Elbe River in one direction, and from the city of Magdeburg to the town of Bernburg in the other."

According to Fuchs and DeLauny¹ the saline formation near Stassfurt is situated at the bottom of a vast triassic deposit surrounding the city of Magdeburg. The quantity of sea water which evaporated to produce saline deposits of more than 500 meters in thickness must have been enormous and the rate of evaporation great. It appears that a temperature of 100° would have been quite necessary, acting for a long time, to produce this result.

These authors therefore admit that all the theories so far advanced to explain the magnitude of these deposits are attended with certain difficulties. What, for instance, could have caused a temperature of 100°? The most reasonable source of this high temperature must be sought for in the violent chemical action produced by the double decompositions of such vast quantities of salts of different kinds. There may also have been at the bottom of this basin some subterranean heat such as is found in certain localities where boric acid is deposited.

Whatever be the explanation of the source of the heat it will be admitted that at the end of the permian period there was thrown up to the northeast of the present saline deposits a ridge extending from Helgoland to Westphalia. This dam established throughout the whole of North Germany saline lagoons in which evaporation was at once established, and these lagoons were constantly fed from the sea.

There was then deposited by evaporation, first of all a layer of gypsum and afterwards rock salt, covering with a few exceptions the whole of the area of North Germany.

But around Stassfurt there occurred at this time geologic displacements, the saline basin was permanently closed and then by continued evaporation the more deliquescent salts, such as polyhalite, kieserite, and carnallite, were deposited.

These theories account with sufficient ease for the deposition of the saline masses, but do not explain why in those days the sea water was so rich in potash and why potash is not found in other localities where vast quantities of gypsum and common salt have been deposited. It may be that the rocks composing the shores of these lagoons were exceptionally rich in potash

¹ *Gites Mineraux*, 429.

and that this salt was, therefore, in a certain degree, a local contribution to the products of concentration.

Through the ages of the past, the rich stores of plant food have been steadily removed from arable fields and apparently forever lost. But in point of fact no particle of it has been destroyed. Even the denitrifying ferments described by Springer, Gayon and Dupetit, and Muntz, reduce only to a lower stage of oxidation or restore to a gaseous form the nitric nitrogen on which alone vegetables can feed. But electricity, combustion, and the activity of certain anaerobic ferments herding in the rootlets of legumes and other orders of plants, are able to recover and again make available this loss.

Lately Winogradsky and Warington have shown that an organism can be grown in a sugar solution containing certain salts, and excluding all nitrogenous matter save the free nitrogen of the atmosphere, which is capable of oxidizing and assimilating this inert gas. In a solution containing 7 grams of sugar as high as 14 milligrams of nitrogen have been fixed.

Warington says in speaking of this phenomenon:

“That a vegetable organism should be able to acquire from the air the whole of the nitrogen which it needs, is certainly very remarkable and is an extraordinary fact both to the physiologist and the chemist.”¹

The fact that a few million years may supervene before the particle that is carried off to-day as waste may return to organic life, shows the patience rather than the wastefulness of nature.

As a result of this general review of the migrations of plant food, the reassuring conclusion is reached that there is no danger whatever of the ultimate consumption or waste of the materials on which plants live. Circumscribed localities, through carelessness or ignorance, where once luxuriant crops grew, may become sterile, but the great source of supply is not exhausted. In fact, as the rocks decay and nitrifying organisms increase, the total store of plant food at the disposal of vegetation may continue to grow. When we join with this the fact that the skill of man in growing crops is rapidly increasing, we

¹ *Chem. News*, Oct. 13, 1897, 170.

find no danger ahead in respect of the quantity of human food which may be produced.

Only the novelist might be able, by the aid of an unfettered imagination, to say how many human beings the United States alone will be able to feed in comfort. With the aid of scientific agriculture, with the help of the agricultural chemist we may safely say that a thousand million people will not so crowd our means of subsistence as to make Malthus more than a pleasing theorist. As I pointed out in my vice-presidential address at Buffalo, the death of humanity is not to come from starvation but from freezing, and many a geologic epoch will come and go before this planet dies of cold.

A NEW FORM OF AIR-BATH.¹

BY EWALD SAUER, PH.D.

IN a recent article on the prevalent forms of air-baths, H. Petersen shows² conclusively that the designs ordinarily in vogue, whether made from copper or from aluminum,³ are far removed from the ideal of such an apparatus. The deficiencies are chiefly in the direction of variable temperature and insufficient ventilation for the purpose of rapidly removing the liberated steam. The use of jacketed air-baths, as Soxhlet's apparatus,⁴ while providing for constant temperature, limits the range of temperature to the boiling points of the liquids employed, and is subject also to limitations in size.

In order to obviate these difficulties, I have designed an air-bath, which while resembling externally the ordinary forms, differs from them in a few essential points. The main feature is the introduction of two bottoms which are connected with each other by several open tubes. These two bottoms are also joined together in the front and in the rear, while on the sides the space is open. A funnel-shaped opening in the center of the lower bottom allows the flame of an ordinary burner to freely

¹ Read before the Cincinnati Section, Oct. 14, 1893.

² *Ztschr. angew. Chem.*, 1892, 36.

³ *Ber. d. chem. Ges.*, 1892, 3637-40.

⁴ *Ztschr. angew. Chem.*, 1891, 363-68.