A.
Section of ditch near Vestaburg, showing light Sphagnum peat over dark peat.

LEGEND A.
- (*a.*) Living Sphagnum.
- (*b.*) Sphagnum peat.
- (*c.*) Shrub remains.
- (*d.*) Sedge rootstocks.
- (*e.*) Pond Lily rootstocks.
- (*f.*) Laminated peat.

B.
View of surface near ditch, showing corresponding vegetative zones.

LEGEND B.
- (*a.*) Shrub zone.
- (*b.*) Grass zone.
- (*c.*) Sedge zone.
- (*d.*) Pond Lily zone.

PEAT

ESSAYS ON ITS

ORIGIN, USES AND DISTRIBUTION IN MICHIGAN

BY

CHARLES A. DAVIS

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LETTER OF TRANSMITTAL.

OFFICE OF THE STATE GEOLOGIST,
LANSING, MICHIGAN, November 20, 1906.

To the Honorable, the Board of Geological Survey of the State of Michigan:

Hon. Fred M. Warner, President.
Hon. W. J. McKone.
Hon. Patrick H. Kelley, Secretary.

Gentlemen:—I herewith transmit to you for publication in your report for 1906, a series of papers on peat, prepared by C. A. Davis, of Ann Arbor. They are the fruit of a happy marriage of botany with geology, and should not be separated. While on the one hand they are an original and important contribution to the botany of peat and the peat producing flora, they are of value in many ways to the geologist, and to any one interested in the promotion of legitimate industry. Information about peat has been too much left to the one-sided investigation of the promoter, who, in his over zeal, may ruin a really desirable development by over estimates of the profits and under estimates of the cost.

Prof. Davis has endeavored to make clear, in the following papers, some of the facts regarding the peat deposits of Michigan which should be of practical value to those who contemplate developing such deposits for commercial purposes.

Some of the more important of these facts are:

That peat deposits are quite variable in structure and origin, but their structure is primarily dependent upon the form of the land surface upon which they are found, and the height of the water above this while they are being formed.

That the most important peat deposits and those most likely to be of commercial value, are found in depressions, or valleys, which have been filled, or partly filled, with peat, through the growth and decay of various groups, or associations, of plants, which succeed each other in a very definite and orderly manner, according to certain laws of plant growth.

That there are many species of plants concerned in peat formation, but of these, the ones growing in the water and a few grass-like plants growing slightly above the average level of the water, are much more important than any others.

That there usually is no relation between peat and the vegetation growing upon its surface. The character of the vegetation is entirely governed by certain laws of plant growth, and primarily by the level of the water in the deposit. The surface vegetation generally gives no clue to the quality of the peat.

That Sphagnum moss is not an important plant in peat formation in the area under discussion, as it is not present until late in the history of the development of any class of peat deposits.

That certain types of peat deposits are of irregular structure and others are free from irregularity, but only careful study of sections can demonstrate these facts for given deposits.

Very respectfully,
ALFRED C. LANE,
State Geologist.

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PART I.

PEAT AND ITS ORIGIN.

THE ECOLOGY OF PEAT FORMATION IN MICHIGAN.

ECOLOGY OF PEAT FORMATION IN MICHIGAN.

Introduction.

While peat has been commonly used for fuel in northern and western Europe from remote antiquity, and its use is still large and apparently increasing in Germany, Holland, Russia, Denmark and Sweden,[1] it has not been brought to the attention of the people of Michigan until recently, that great quantities of this fairly efficient fuel exist within the boundaries of the state, as much as one-seventh of its entire area, or about 5,200,000 acres, being estimated as swamp or muck land,[2] although not all of this is underlain by peat. The prolonged strike of the hard coal miners in 1902-3, followed by the scarcity and high prices of all sorts of fuel, taken in connection with the rapidly disappearing forests of the state, led to the consideration of all possible sources of increasing the available fuel supply, and among these, peat was mentioned and its availability investigated. After some preliminary tests, at several places in the state, plants were projected for the purpose of putting peat into such form that it could be transported cheaply and placed upon the market, in competition with other fuel, especially with coal. A brief preliminary report upon peat in Michigan, prepared by the State Geologist, Mr. Alfred C. Lane, appeared in the Annual Report of the State Geological Survey for 1902, and to the writer was assigned the task of making some more extended investigations into the method of peat formation and accumulation, the causes for its variations in structure and appearance, and its distribution within the state, especially in the Southern Peninsula, and out of these investigations the present paper has developed.

In a discussion having the scope attempted here, certain elementary principles must be laid down in order that the position of the writer may be clear, especially since the paper is intended for the non-technical as well as the technical reader, but such statements will be made as brief as is consistent with clearness.

The Chemical Composition of Vegetable Matter.

All organic matter, whether of animal or vegetable origin, is made up principally of three, or, at most four, chemical elements, of which one only, carbon, is a solid, the others being gases. Besides these three or four important elements, others, including some of the metallic elements, are always present in vegetable matter, but only in small quan-

[1] Carter, W. E. H., Peat Fuel; Report of Ontario Bureau of Mines, 1903, p. 193.
[2] Towar, J. D., Mich. State Ag. College Ex. Station, Bull. 181, p. 157, 1900.

tity, and are grouped together as ash in the analyses and may be neglected as immaterial in the present paper.

When uncombined, or only partly combined with oxygen, carbon is the most important fuel element, and all forms of fuel have it as a chief constituent and are good or poor, as they have much or little of this element is available form in them. In vegetable matter, such as wood, the leaves and the stems of plants, carbon is associated with two gases, hydrogen and oxygen, to form, among others, the complex substances, cellulose, or ordinary vegetable fiber ($C_6 H_{10} O_5$) and lignin, or woody fiber ($C_{35} H_{24} O_{20}$). Nitrogen, also a gas, is present in small quantities in certain vegetable substances, associated with the three elements already named.

In both cellulose and lignin, as will be seen from the chemical formulas, the three elements are built into complicated molecules, having many atoms of each, and hence, relatively to the more simple inorganic molecules, unstable and easily decomposed.

Agents of Decomposition of Vegetable Matter.

When allowed to remain exposed to the air, in the presence of moisture, it is well known that most forms of vegetable matter rot, and finally disappear entirely, and such decay has been described as a form of oxidation,[1] similar to, if not identical with, that which occurs when the same sort of material is burned; that is, as a purely chemical process. This process is not, however, directly due to the action of the air, or any of its gaseous constituents, or to moisture. Perfectly dry vegetable matter will keep indefinitely in the air, as is shown by innumerable articles in common use. In like manner, we find that wood and similar material of vegetable origin will keep for very long periods of time when entirely submerged in water. The decay of vegetable matter is really a series of complicated changes, due to the growth and development of living organisms in the decaying matter. These use part of the material of which the vegetable tissue is composed for their own nourishment and growth, and thus break it down into simpler compounds. The organisms which thus produce decay are mainly plants of simple structure, and often of microscopic size, and when they are not so small, their lack of color, and their intimate association with the tissues in which they grow, render them very inconspicuous. These plants are bacteria and fungi, and are aided in bringing about decomposition by many types of animals.

Like all other plants, these decay-producing forms need both air and moisture in order to grow, and, moreover, the moisture must be present in proper amount, too much water being as detrimental to their growth as too little, and where air is excluded they do not thrive.

Varying Rate of Action of the Decomposing Agents.

When the conditions are favorable for these plants to grow (that is, sufficient moisture, air, and a favorable temperature), they may develop with great rapidity, and bring about quick and complete reduction of vegetable material to simple gaseous compounds, such as car-

[1] Scott, W. B., Introduction to Geology, 1897, p. 133.

bon dioxid (CO_2), ammonia (NH_3), and water, and the vegetable matter as such, ceases to exist. Thus, in moist woodlands, even the hardest wood soon becomes rotten, then loses its woody structure entirely, and finally vanishes, leaving possibly a trace of dark soil to show that it once existed, but nothing that shows that it was wood. The fallen leaves in the forest last much less time than wood and soon become indistinguishable from the soil of which they become a part.

If conditions are less favorable the bacteria and fungi do not thrive, the decay of wood and leaves goes on more slowly and is less complete, so that in wet woods, where the temperature is low, wood and leaves may lie for several or many years with little change, and in dry woods such débris may accumulate until a thick layer is formed, only the lower parts of which are decomposed. If, because of very unfavorable conditions, some kinds of the destructive organisms cannot exist, and others are reduced in numbers, a slow and partial decomposition may take place, in which the more easily broken-down compounds of the vegetable matter disappear, leaving the more resistant ones almost unchanged. In such cases, the original mechanical form of the affected tissues may be entirely lost, while the chemical composition of the larger part of them is only slightly affected, and such changes as do take place go on slowly.

In some cases, where water containing mineral matter, or certain organic matters in solution, is present in large excess, chemical changes not produced by organisms may occur and in such cases it is natural that part of the gaseous elements of the molecules which are undergoing change, being chemically more active than the solid carbon, and more free to move, should separate from the molecule first, and leave the carbon associated with smaller proportions of hydrogen and oxygen.

What Peat Is.

From the foregoing considerations it is apparent that vegetable matter may undergo decomposition under a variety of conditions, dependent upon which the amount of change will vary. Some of these conditions permit the changes to result finally in complete decay, and in nearly complete disappearance of the substances, and others simply allow the process to result in the loss of the more easily changed compounds, and of the gaseous elements, while the greater part of the material retains its original form and mechanical structure.

Peat, when examined with a view to determining its origin, will usually, even to the unaided eye, show vegetable structure, and frequently well-preserved plant remains will be found in it in large quantity. If decay and disintegration have gone so far that the larger plant structures have disappeared, it is still usually possible to identify the vegetable tissue-elements, cells, or parts of cells, by the aid of a compound microscope. It is then clearly demonstrable that peat is vegetable matter which has become partly decomposed. In the process of decay, it has been more or less completely changed chemically, and usually mechanically, but in such a way that it still retains a large part of the carbon, together with more or less of the other more readily dissipated volatile matters which wood and other forms of plant structures contain.

Description of Peat.

When dry, peat is of a color varying from a light yellowish brown to nearly black, and when wet the shades of color are all much deepened, the darker ones appearing quite black. It also varies in texture and structure from a loosely felted, slightly coherent mass of plant remains having low specific gravity, to a compact, structureless material which is relatively heavy, quite plastic and sticky when wet, and which dries into firm, tough masses. There seems to be, in general, a close relationship between the color and texture of different types of peat, the lighter colored types being coarser in texture, and approaching ordinary dried vegetable litter in appearance, while the darker sorts are nearly as structureless as clay. In most deposits of peat which have been undisturbed by human agencies, there is a progressive change in color from light to darker shades, and, in texture, from coarse and loose, to fine and compact, as the bed is cut through from top to bottom. The chemical composition of the different types of peat also varies, as shown by the following analyses cited by Ries[1] from Johnson.[2]

Material.	Analyst.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Sphagnum,	Websky	49.88	6.54	42.42	1.16
Peat, porous, light brown, Sphagnum.	"	50.86	5.8	42.57	.77
Peat, porous, red brown,	Jaeckel	53.51	5.9	40.59	
Peat, heavy brown,	"	56.43	5.32	38 25	
Peat, dark red brown, well decomposed,	Websky	59.47	6.52	31.51	2.51
Peat, black, very dense and hard,	"	59.7	5.7	33.04	1.56
Peat, black, heavy, } Best for fuel,	"	59.71	5.27	32.07	2.59
Peat, brown, heavy, } Best for fuel,	"	62.54	6.81	29.24	1.41

From these analyses, which neglect the ash, it is apparent that in the denser and darker peats there is a larger amount of carbon and a smaller amount of oxygen than in Sphagnum, or in the more porous, lighter colored types, amounting to from 8 to 12 per cent increase in carbon and from 8 to 12 per cent decrease in oxygen.

Muck is the name given to dark colored, thoroughly decomposed peats in which there is a considerable mixture of mineral matter, but as this is very variable in quantity, there is no sharp distinction to be made between peat and muck, as all peat contains some mineral matter, which appears as ash when the peat is burned.

In the natural state, peat is always saturated, or nearly saturated, with water, except in the uppermost layers, and in very dry times.

Occurrence.

Peat usually occurs upon gentle slopes, flat areas, and in more or less shallow depressions in the earth's surface, which have either no direct drainage, or are poorly drained, so that the surface is always wet or covered by water. In these places are formed eventually the accumulations known as "bogs," "marshes," and "swamps." Names for the same forms of deposit are "morass,"[3] "moor"[4] and fen, but these, in America, are not common terms, or are not in use, and do not need discussion. The first three, however, are used so interchangeably that it may be well to define them in the sense in which they are used in this paper. The

[1] Ries, H., 21st Report of the New York State Geologist, 1901, pp. r. 58, 59.
[2] Johnson, Peat and its uses, p. 24.
[3] Shaler, N. S., Fresh-water Morasses of the United States, U S. G. S. 10th An. Report, p. 261.
[4] Coulter, J. M. Plants, Chicago, 1900, p. 187.

writer has not adopted the use of the German word "moor" as a substitute for "bog," because the English word "moor" is already in use with a fairly constant meaning, namely, to designate a broad, flat upland with light soil, covered with grasses and shrubs, and while such moors may be more or less covered with peat in some cases, they are not generally peat deposits. A bog is an area of wet, porous land, on which the soil is made up principally of decayed and decaying vegetable matter, so loosely consolidated, and containing so much water, that the surface shakes and trembles as one walks over it. The vegetation upon the surface is variable, but it is characteristically either some species of moss or of sedge, or grass, or a combination of two or more of these with shrubs and even small trees. This is in part identical with Cowles'[1] undrained swamp, and is well illustrated by many examples in various parts of the Southern Peninsula, of which Mud Lake, in sections 1 and 12, T. 1 S., R. 5 E., about one and one-half miles west and nine miles north of Ann Arbor, the south and east border of Half Moon Lake, in Gratiot county, in sections 5 and 6, T. 12 N., R. 4 W., and a bog near Hobart Station, 5 miles southwest of Cadillac, on sections 30 and 31, T. 21 N., R. 9 W., and the region adjacent are types.

A marsh has a firm soil; that is, not easily shaken when walked upon, although it may be soft and very wet, even submerged, and the vegetation upon it is principally grass-like; that is, with long narrow leaves, and weak, short-lived aerial stems. Shrubs may occur upon marshes, and where they are present not infrequently form thickets. The development of typical marshes is much greater than that of bogs as defined above, and much larger areas of marsh are to be found in more or less accessible places. In the southern part of the state, the Detroit and St. Clair rivers, the shores of Saginaw bay, in Akron and Wisner townships, Tuscola county, and inland, a considerable part of James township, Saginaw county (T. 11 N., R. 3 E.), several sections on the Ann Arbor R. R., in T. 9 N., R. I W., and considerable areas of the shores of the lakes about Lakeland in Livingston county, are examples. In marshes of this character the depth of peat may be slight or considerable.

A swamp, according to the writer's usage in this paper, has trees and shrubby plants as the most important part of the vegetation, the soil being, as in the case of the marsh, firm, but wet, even, at times, to flooding. The swamps are even more common than marshes and great areas of the state were formerly covered by this type of formation, which have long since been cleared, drained, and converted into agricultural land. One of the most extensive swamps seen in the Southern Peninsula of Michigan, by the writer, is located due west from West Branch, in Roscommon county, and is traversed by a state road to Houghton Lake. The timber in this tract is largely Tamarack, *Larix laricina* (DuRoi) Koch, and Arbor Vitæ, *Thuja occidentalis* L. Smaller swamp areas in nearly natural condition exist in many parts of the southern tiers of counties, notably at various points along the rivers, and around many of the lakes which occur here.

These types all intergrade more or less among themselves, and with swamps and marshes in which the soil is not of vegetable origin; hence

[1] Cowles, H. C., The Physiographic Ecology of Chicago and vicinity, Bot. Gaz. XXXI, 3, pp. 147-154.

no absolutely sharp differentiation can be made unless a rather elaborate set of compounds be devised. Not infrequently the three types may exist in the same basin and, as at Mud Lake, referred to above, it is possible to pass from one type to the other in crossing the deposit around the lake, and in many other cases around lakes the same relationship exists, the bog lying next the lake, the marsh next inshore, and the swamps extending back often to the high ground which may have formed the shores of the lakes originally. This, as will be seen later, is a perfectly normal arrangement, and one easily explained.

Of the three terms, "bog" is the one most often used in describing deposits of peat, but this is perhaps an inheritance from English and other European literature on the subject, for in northern Europe the peat is very often found in bogs, as described above.

Since peat is formed on undrained areas or in depressions, the extent and depth of a given deposit is generally determined by that of the plain or basin in which it lies, but as pointed out by Shaler,[1] it is possible for the area of peat formation to be extended outward from a center under certain climatic conditions by the encroachment of certain species of plants which may be good peat formers upon the area occupied by those which are not large contributors of vegetable matter. This has not been noted by the writer in his studies in Southern Michigan. Since, as will be shown later, the conditions for rapid accumulations of peat are more favorable in shallow basins than in deep, and in those of limited extent than in large, there are many more small deposits than large ones, and it is rare to find accumulations of more than forty or fifty feet in depth, although deeper ones are known to exist.

Geographical Distribution of Peat.

The conditions favoring the formation of peat are such that it is found most commonly in moist and cool or cold parts of the earth, hence in northern Asia, Europe and North America it occurs in great abundance, but that it is not lacking in the southern hemisphere is shown by the account of the extensive deposits of this substance on the islands on the southern coast of South America by Charles Darwin,[2] who states that the climate of the southern part of America appears particularly favorable to its production. Ries[3] states that, "Peat deposits are found chiefly in north temperate climates, especially in moist ones. Many thousand acres of the North German plain are underlain by deposits of peat, while in Ireland alone it is estimated that there are 1,576,000 acres of flat bog, and 1,254,000 acres of mountain bog. Russia is said to have 67,000 square miles of peat land, and there are several million acres in Norway and Sweden, while extensive deposits are not lacking in France and Holland. Peat bogs are common in New York, Pennsylvania, Michigan, Wisconsin, and Minnesota."

Le Conte[4] quotes estimates by Dana, that Massachusetts has 15 billions of cubic feet of peat and also states that California has large areas of imperfect peat in the "tule lands" about the mouth of the San Joaquin river and elsewhere and that extensive swamps exist in Virginia,

[1] Op. cit., pp. 284-285.
[2] C. Darwin, Naturalist's Voyage around the world; 1888, pp. 287-288.
[3] Op. cit. p. 65.
[4] Le Conte, J., Elements of Geology. 1896. p. 147.

and North Carolina. In Europe 1-10 of the whole surface of Ireland, large parts of Scotland, England and France are covered with peat. The bog of the Shannon river is fifty miles long and three miles wide, that of the Loire in France is 150 miles around. In Canada, according to Carter,[1] peat bogs are numerous, and, in extent and wideness of distribution are probably not exceeded by those of any other country of equal area. North of the height of land, say 50 miles south of James Bay, peat muskeg covers the face of the earth for hundreds, perhaps thousands of square miles, and stretches northward along the westerly shores of Hudson's Bay. In the United States it is estimated that there are 75,000,000 acres, or 120,000 square miles of swamp land.

This distribution of peat deposits seems to be due in large measure to a combination of factors, among which are abundant precipitation, regularly distributed throughout the year, slow percolation and slight evaporation from the surface, and small run off of the surface water, because of poor drainage. There must also be a mild season sufficiently long to permit plants to grow with vigor and abundance enough to furnish accumulations of débris from which peat may develop. These factors are all operative in the cold temperate regions of the continents mentioned above as areas of extensive peat deposition. They are poorly drained, since they have been abandoned recently by the ice of the glacial period, and abound in depressions and broad flat divides, and other plains from which the water is but slowly drained by existing streams. The growing season is long enough so that the vegetation is luxuriant, and in the regions of greatest peat deposition it is cool and moist. The soil temperature is low, which tends to hinder percolation from the upper to the lower levels of the soil by increasing the viscosity of the soil water, while the low average temperature of the air is a check upon evaporation from the soil or from water surfaces, since at low temperatures the air is very readily saturated with moisture. The effect of these factors is to keep the surface of the soil constantly wet, and to permit the water which falls upon it to remain there, and accumulate in all depressions.

Distribution of Peat in Michigan.

Location: Michigan lies between the parallels 41° 45′ and 48° 20′ N. latitude and between 82° 25′ and 90° 34′ W. longitude. It is divided naturally by the Great Lakes into two distinct parts, the Upper or Northern, and the Lower or Southern Peninsulas. The greatest length of the northern portion is from east to west and is 318 miles, the width from 30 to 164 miles. The southern portion has its greatest length from north to south, 277 miles, and its width at the widest part is 259 miles. The total area of the state is 58,915 square miles, and the coast line is over 1,600 miles in length.

Since the studies from which conclusions have been drawn in the present paper were made in the Southern Peninsula, only that part of Michigan will be considered in the following brief discussion of the climate and physiography.

The fullest account of the climate of the state is by the late Prof. A.

[1] Carter, W., E. H., "Peat Fuel; Its Manufacture and Use," Report of Ontario Bureau of Mines, 1903, p. 202.

Winchell[1] which still is, in general, correct in its conclusions, although many additional data have been collected since its publication.

Precipitation: Lane[2] gives the average precipitation for this portion of the state as some 32 inches, and in the rainfall maps of climate charts of the United States[3] the Lower Peninsula lies in the region having between 30 and 40 inches normal precipitation with a small area about Little Traverse Bay having over 40 inches.

The same series of charts show that the precipitation is between 6 and 9 inches in the first quarter of the year, January to March; between 9 and 12 inches for the second and third quarters; and between 6 and 9 inches for the fourth quarter. The period included in these charts is from 1870 to 1896.

The following table cited by Lane[4] from Winchell shows substantially the same thing regarding the distribution of the precipitation during the year:

Distribution of Precipitation in Michigan by Seasons.

Season.	Upper Peninsula.	Lower Peninsula.	The State.
Spring	19%	25.8%	23.8%
Summer	27	28.7	28.3
Autumn	28.8	27.3	27.7
Winter	22	19.1	20

These data make it appear that the season of greatest rainfall is the summer and fall, and as this coincides with the season of greatest heat and consequent evaporation, it is evident that this distribution of rainfall is an important aid in the peat formation[5] and in the warmer parts of the state, may be the primary factor, since it prevents the great drying out of the soil moisture which would take place if seasons of long drought occurred annually.

The rainfall is not evenly and uniformly distributed over the Southern Peninsula but in the southern part, especially the southwestern, is an area of greater precipitation than occurs further north, and the valleys of the Saginaw tributaries have less to a marked degree than is found elsewhere, except in small areas. The western side of the Southern Peninsula has a larger rainfall than the eastern, except a narrow strip from the mouth of Saginaw Bay northward. The differences in the total amount of rainfall are not however large, and taking into account differences in temperature, soil and surface configuration, it is probable that there are few areas of the same size in the United States more evenly watered than that under discussion.

Temperature: The average annual temperature of Southern Michigan varies nearly 10 degrees in going from the southern to the northern ends

[1] Winchell, A., in Tackabury's Atlas of the State of Michigan, ed. by H. F. Walling. 1st. ed. 1873, 2nd. ed. 1884. Proceedings Am. Assoc. Adv. Sci., Troy meeting, 1870.

[2] Lane, A. C., Water Resources of the Lower Peninsula of Michigan, Water Supply and Irrigation Papers, U. S. G. S., No. 30, 1899.

[3] Climate Charts of the U. S. Weather Bureau, Washington, D. C., 1900. See also Jefferson Report Mich. Acad. Sci., VIII., 1906, and Leverett, F., Flowing wells and Municipal Water Supplies of the Southern Peninsula of Michigan, W. S. & I, Paper 183 U. S. G. S., 1907, p. 10.

[4] Op. cit. p. 49.

[5] Shaler, op. cit. p. 263.

of the peninsula, and the same may be said of the average maximum and average minimum temperatures, but the isotherms do not run uniformly at right angles with the north and south axis of the state but are variously curved[1] showing that the temperature is profoundly influenced and modified, (1) by the presence of the great lakes on three sides of it, (2) by the great land mass to the south and the southwest, (3) by the high lands in the northern part of the interior of the peninsula. Lake Michigan is especially important in its effects, modifying both the maximum and minimum temperatures very decidedly and as a result of this the climate is more even and milder than that of the region in the same latitude west of the lake. Yet the annual range of temperature is about 116° F. The range of the average mean temperature of the portion of the state under consideration is from 49° at the southern and southwestern parts to 41° in the Straits of Mackinaw, the lines of equal temperature bending northward in the western and southeastern parts, and southward in the high areas in the region northwest and southeast of Saginaw Bay. That is, the western and southeastern parts are warmer and the highlands cooler than those immediately adjacent to them.

Sunshine: The amount of direct sunshine a region receives is important in a discussion of the vegetation of that region, and the following has been compiled from the maps referred to above.[2] The Southern Peninsula receives, with Wisconsin, part of Illinois, Indiana and Ohio, parts of Pennsylvania and New York, and a portion of New England, between 40% and 50% of sunshine during the year, compared with less than 40% in the Northern Peninsula and more than 70% in the arid region of Arizona and adjacent territory.

During January this sinks to less than 20% in a considerable portion of the western part of the peninsula and is only above 40% in the southeastern part. The area below 20% is the only one in the United States. In July, on the other hand, a very considerable part of the peninsula has over 60% of sunshine, the area extending across Indiana into northern Illinois to the Mississippi, and constituting the only area with so high a total of sunshine east of that river. The rest of the Southern Peninsula has between 50% and 60%. The effect of this relatively large amount of sunshine, during the growing season should be to increase the development of vegetation and to promote its vigorous growth, as well as cause a relatively high range in temperature.

It is thus evident that the Southern Peninsula of Michigan has a sufficiently mild and moist climate to produce abundant plant growth, and that the rainfall is so evenly distributed that no long periods of excessive drought normally occur, but on the other hand, the periods of greatest heat are also times of largest precipitation. The differences between the average temperature of the southern and northern parts are large enough to make a marked difference in the humidity of the climate, if the amount of precipitation is approximately the same, because the air of the cooler region will be constantly more near the saturation point. In this part of the state, also, the periods of greatest heat are shorter and less frequent than in the southern portion, which fact is important in considering evaporation effects upon vegetation and moist or wet surfaces. That is, in the northern part of the Southern

[1] See Lane, op. cit. pp. 49-53.
[2] U. S. Weather Bureau. Op. cit.

Peninsula, because of the differences in temperature alone, more of the land surface will be available for the formation of peat than in the southern part of the same area, because the drying effects of highly heated air are absent there. The efficiency of this agency is relatively greater for the higher temperatures than for lower ones, since the capacity of the air to take up moisture increases more rapidly above 50° F. than it does below it.

Physical Features: To these climatic conditions which are, on the whole, favorable to the abundant formation of peat, are added certain physical surface features which are also very favorable. Shaler[1] says, "In the conditions which determine the formation of swamps, the shape of the land is generally of most importance." The Southern Peninsula of Michigan is, geologically speaking, new land, recently exposed to the erosive agencies which have not yet had time to develop a complete drainage system. Because of this, there are great numbers of deep hollows, slight depressions and flat areas, in and upon which water accumulates and from which it drains away very slowly, or not at all, forming lakes. Moreover, the agencies which shaped a great part of the surface of Michigan, were such that they left it exceptionally rough, after entirely obliterating the older surface and its systems of drainage, at so recent a time that the new drainage is still in an undeveloped stage. In traveling over the Southern Peninsula one is constantly impressed by the facts that about its borders, for a varying distance from the Great Lakes, the country is quite flat and free from either marked elevations or depressions. Proceeding inland however, the character of the surface changes and often abruptly, becoming rolling, the plain giving place to a series of ridges and hollows, which seem distributed over the land without order or plan. Often between areas of such rolling country will be found broad plains and valleys, which, though relatively flat, are not smooth, but contain frequent depressions in which are found lakes and marshes. The broader plains have a somewhat different geological history from the interior rolling country, but it is sufficient to say that in the marginal plains, while rarely considerable deposits of peat are accumulated, in general such accumulations are shallow and not of commercial extent. In the rough and rolling areas, however, as has been pointed out above, there are many undrained depressions and places where water stands above the land surface permanently, and in this territory, the region of moraines, gravel and till plains, left by the ice of the last glacial period, there are very numerous deposits of peat, many of which are extensive enough to warrant commercial development, and when all the available deposits, large and small, which are to be found in this region are taken into account, they represent an enormous amount of stored-up fuel.

Classification of Michigan Peat Deposits.

Various methods of classification for swamps and peat accumulations have been proposed, and more or less satisfactory schemes for grouping them may be made.

Shaler[2] considering all inundated lands, uses a system based upon, first, the kind of water by which the land was covered, fresh or salt, and

[1] Shaler, N. S., Op. cit. p. 263.
[2] Shaler, N. S., Op. cit. p. 264.

then under fresh water swamps, considers the source of the water, whether from rivers, lakes, etc.

Schimper[1] under the paragraph "moors," states that rich formation of peat on wet soils leads to the production of moors, which occupy very large areas, especially in the cool and moist districts of the cold temperate belt, and classifies them according as they have or have not a limey substratum as "meadow-moors" rich in lime, and "high-moors" poor in lime, with the center built up higher than the margins, hence the name. The same nomenclature was adopted by Fisher,[2] Fruh,[3] Koller[4] and others, and is evidently the ordinary usage in Germany since Eiselen[5] says that, "in East Friesland, Holland, the Holstein region, etc., they usually divide peaty areas into the so-called high and meadow moors."

A very casual study of peat bodies will convince any careful observer that not all of them have been formed in the same way, and a little consideration of the possibilities of each formation will make it apparent that there may be a number of possible methods by which such accumulations have come about. For convenience of discussion the writer has grouped the peat deposits of Michigan in several ways, taking as a basis of the classification, various points of view and elaborating each under a separate head.

Peat Deposits Classified According to the Form of Land Surface Upon Which They Have Been Formed.

This seems the most fundamental basis for a scheme of classification, and hence is considered first. Peat is formed over:

A. Depressed surfaces or hollows.

B. Surfaces not hollowed out.

Class (A) may be subdivided more or less minutely, but of easily recognizable forms of closed depressions, the following are most worthy of consideration:

1. Lake basins of the "tarn" type.
2. Shallow lake basins of the ordinary type.
3. Hollows not permanently filled with water.
4. Hollows in sand dunes.
5. Hollows formed by dams.
    a. Dams formed by differential uplift or tilting.
    b. Dams formed by hard rock outcrops.
    c. Dams formed by glacial ice, morainal dams.
    d. Dams formed by wave, wind, and ice action along the shores of the lakes.
    e. Dams formed by rivers and streams at flood time, cutting off portions of their flood plains, or of their channels.
    f. Driftwood dams in sluggish streams.
    g. Beaver dams.

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1 Schimper, A. F. W., Plant Geography upon a Physiological Basis. Trans. by Fisher. 1903. p. 657.
2 Fisher, Chem. Technol. der Brennstoffe, 1897.
3 Fruh, I., Torf und Dopplerit, Zurich, 1883.
4 Koller, T., Die Torf Industrie, Wien, 1898.
5 Eiselen, J. C., Handbuch oder............Anleitung zur............Kentniss des Torf wesens, Berlin, 1802.

Class (B) may also be subdivided into:

1. Poorly drained till plains.
2. Broad divides.
3. The floors of glacial drainage valleys.
4. Lake and stream terraces.
5. Deltas of streams.
6. Slopes over which seepage spring waters flow.
7. Northern bogs, in which peat forms on slopes, i. e. "climbing bogs."

Among the thousands of small lakes in the Southern Peninsula, there are several well-marked types, among which two, tarns and ordinary lakes, from their frequency, may be cited. These are formed in hollows in glacial moraines, or in the depressions which occur so frequently in the gravel plains, which mark the lines of drainage from the front of the glacial ice. The term "tarn" is applied to any of these small lakes in which there is no visible inlet, and such lakes as the "Sister Lakes" a short distance west of Ann Arbor, Whitmore Lake, 10 miles north of that city, and Bass and Rock Lakes near Vestaburg, Montcalm county, are examples of this class. Whitmore Lake is also an example of the type filling a depression in a plain, as are Rock and Bass Lakes. Many of the lakes in Lyndon Tp., T. 1 S., R. 3 E., are excellent examples of morainal lakes, and several of these, like Cedar Lake, in section 9, are tarns as well. Lakes of the ordinary type, with well marked inlets and outlets are so numerous as to need no illustration, since they occur so frequently that hardly a portion of the Southern Peninsula, except the region about Saginaw Bay, is without them.

There are abundant illustrations also of the third class of depressions, those not filled permanently with water, especially in the morainal parts of the state, which, while they have considerable water in them at times are not continuously occupied by lakes and may be termed intermittent lakes in some cases, while in others, they may represent filled lakes, or may be merely marshy. Peat accumulates in them, in some cases, and in others does not, the general rule seeming to be that in the southern part of the state, if shallow, they contain little peat, while north, they are usually partly filled with peat, whether shallow or deep.

The sand dune regions of the Southern Peninsula are chiefly in the immediate vicinity of the Great Lakes, and here between dunes will often be found swampy areas, formed apparently by the fact that the dunes rest upon a clay substratum, upon which the water which soaks into the sand of the dunes, accumulates in sufficient quantities to induce bog, swamp or marsh conditions. The shores of Lake Michigan, where not too high, the region around Saginaw Bay, and of Lake Huron north of that Bay, give numerous examples of this type of depression, while in Vassar township, Tuscola county, may be found occasionally a swamp which has developed in an inland dune region.

The types of basins formed by dams are not always easily distinguished from other depressions, but frequently the dam itself is still easily identifiable, and as the depressions were in many cases originally stream valleys they are often long, and narrow in proportion to their length. The long narrow lakes on the west shore of the Southern Peninsula are, many of them, such stream valleys according to Lane,[1] which have been sunk by differential uplift and later closed by bars thrown across the mouth of the valley by wind and wave action. In a region so generally covered by glacial moraines as the higher parts of the Southern Peninsula it would seem easy to point to moraina dams in numbers, but relatively few are known to the writer. Such a dam crossed the Huron river valley at Ann Arbor at an early stage in the retreat of the Maumee Lobe of the ice sheet to the Lake Erie basin, but it was apparently a very temporary affair, and was soon washed out, and this is apparently the fate of most of such dams to stream valleys, for we find not infrequently that streams have been crossed by moraines which at one time converted their valleys into temporary lake basins. Such a dam held back the waters of the Cass river near Vassar for a time, and the Pine river near St. Louis, and also near Alma, was evidently dammed by small moraines. The height of these dams and their looseness of texture was usually unfavorable to their permanence, for as soon as the water began to run over them they rapidly washed out.

Much more permanent are the barriers, which are built by wave and current action and ice shove in the winter, across the mouths of indentations on the shores of the larger lakes, and which tend to straighten the shore line by cutting off the bays and making them into independent basins. Almost every lake which had originally any irregularities in its shore line shows some such cut off bay. The best illustrations of dams of this type may be found upon the west shore of the state, where wind, waves and current action are all working together to straighten the shore line, and such lakes as Pine Lake near Charlevoix and Intermediate and Torch Lakes on the east side of Grand Traverse Bay and a large number of others show how efficient these dams are.

An excellent example of this type of lake on the eastern side of the state, is Tobico Lake, in Bay county, a short distance north of West Bay City, where the long current-formed sand spit has cut off from the main body of water, what was until recently a bay. Here also may be seen, a short distance to the west of the present Tobico Lake, and at higher levels, two swamps, formed by the filling of lakes, which were cut off in identical fashion from the main bay during the time when the lakes which preceded Lake Huron covered the land. Tobico Lake is shallow and supports an abundant growth of aquatic plants, and is apparently filling rapidly.

These larger examples are cited because they are so conspicuous, but Littlefield Lake in northern Isabella county, T. 16 N., R. 5 W., has six basins, which have been cut off from the main one, in this case by marl, which has closed up mouths of what were formerly bays. The shore of Saginaw Bay, especially on the east side, has many small, shallow ponds just behind the present shore line, which have been made by the sand ridges heaped up by wind and wave action.

The basins formed by stream action differ in shape and are usually, in Michigan at least, of smaller size than those formed by the agencies just mentioned. They are of two types, the marginal and the "ox-bow." The marginal type is usually developed on the shoreward edge of the flood plain of the stream valley, by the elevation of the bottom of the existing

[1] Op. cit. p. 65.

channel of the stream by depositions during seasons of high water. This gradually raises the part of the flood plain in which the stream runs, and leaves the remoter margins lower, so that when the banks overflow the water finds its way to those lower places and remains there, or finds its way slowly to the stream lower down in its course. Most streams with a wide valley and rather sluggish current show ponds and lakes caused by this form of dam in some parts of their course. Maple river, a tributary to the Grand, the Saginaw river, the Pine river, near Alma, and many other streams are examples showing this form of dam. The type of depression formed by the changes which streams make in their channels during times of flood is best illustrated by the "ox-bow" lakes, but these are by no means the only forms which occur. Streams in the lower and flatter parts of their courses, where their valleys are wide and the material easily eroded, are most likely to furnish illustrations of this form of dam. The streams in this part of their valleys are likely to meander widely and make very tortuous channels for themselves, and in flood times, when the current increases in velocity, and the amount of water is so great that the streams are out of their banks, they cut new channels, straighter and more direct, and close up, in part at least, the old ones, leaving them as elongated depressions of greater or less extent, which are usually wholly or partly filled with water. The Huron river below Ypsilanti, and in fact the greater number of the streams flowing in broad flat valleys throughout the state, afford examples of cut off channels and bends, so that no student of the subject need go far to seek illustrations.

In early times in the Southern Peninsula the streams were often blocked for considerable distances with dams of drift wood, the trunks of trees, washed out from along the banks by freshets, and by the undermining of the banks by shifting currents during the ordinary stages of water. These were usually cleared out of streams as soon as lumbering began, and, except in the wilder and more inaccessible parts of the state, will not be allowed to accumulate again, but the following account of such dams by Desor[1] is interesting and shows how extensive such obstructions formerly were. "We had sailed a day and a half on the principal branch of the Manistique, when we were stopped by an accumulation of tree trunks, forming an obstacle across the river. The rafts, which the Canadians called 'embarras,' are by no means rare in the forest, wherever the gradient of the river is slight. A tree trunk uprooted by the current, and dragged along by the river catches on the side of a meander; if the current does not dislodge it, a second trunk coming along is stopped, others come along and their branches interlacing, they end by forming a barrier, which increases indefinitely. There are some of these barriers which have a considerable area and are very old, since they are often found covered with bushes which have taken root upon the floating trunks. The one we encountered here was not of this kind; it was evidently of recent formation, because it was not more than a dozen fathoms in width. The tree trunks were dry and mainly of the Arbor Vitae."

Another of these obstructions in the same stream is described as several hundred fathoms long and very old, covered by shrubs, among others,

[1] Desor, E., La Foret Vierge, pp. 28-30, Paris, 1879.

the raspberry, which grew "as parasites" on the half rotten trunks of the birches and spruces.

It is not to be questioned that such obstructions in streams did much to hold the water back and create marsh and swamp conditions for considerable distances above them.

Of beaver dams little need be said here, since they are discussed at length in another place, except to point out that the extensive deposit of peat at Capac, seems, in part at least, to have been formed in the ponds created by beavers, since their dams were cut through in developing the drainage system of the deposit, and that the remains of the animals and their dams are frequently found in draining swamps and marshes in the central part of the state.

Types of flat areas belonging to class (B) are widely distributed over the Southern Peninsula and only single instances need be cited to show the characteristics of each. The "till plain" is a nearly level area which probably is the ground moraine of a portion of the glacial ice sheet which melted back at a uniform rate faster than the ice advanced, so that no morainal ridges were formed. Such a plain of rather small extent is found in Washtenaw county north of Ann Arbor. The soil is usually bouldery clay and sufficiently impermeable so that the water stands upon the more level parts of the surface, a part of the time at least, thus tending to cause the development of swamps.

The broad flat divide between the tributaries of different drainage systems is a well marked character of young topography, and is frequently found in the Southern Peninsula, in the higher parts especially. Many of these divides are parts of till plains, and are swampy for the same reason that the plains are. The extensive swamp areas between the Pine river and the Maple river in Gratiot county may be considered as examples of this form of land surface.

By glacial drainage valleys are meant those in which the water from the front of the melting ice sheet flowed away to some lake or to the sea; or in some cases they are undoubtedly the temporary outlets of the great lakes which accumulated for a time between the front of the ice sheet and the high land from which it had recently retreated. These valleys are sometimes of great length, and of considerable width, and may or may not be occupied by streams at the present time. Such a valley is usually very flat in the bottom, and where it is not too sandy or gravelly, may become swampy. The series of marshes and swamps extending southward from Huron county to Imlay City and thence southwestward, is such a channel, while the well known celery swamp south of Ann Arbor and those about Kalamazoo are other examples.

Lake and stream terraces are often nearly flat and because of being covered by impervious clays do not quickly absorb rain water, or that which flows over them from higher levels. The wet shores of Saginaw Bay, the well marked marshy areas about the western end of Lake Erie, and the swamps and marshes upon the terraces of such streams as the Saginaw, the Maple and Huron rivers may be taken as typical of these forms of plains.

Streams, besides forming dams along their courses are continually depositing material at their mouths by which they build up a more or less extensive plain of wet soil to the level of the body of water into which they run. These plains are not usually of great extent, but may develop until they fill large areas of the lakes into which they are built. The delta of the St. Clair river in Lake St. Clair described by J. Leon Cole,[1] and that of the Saginaw river are two of the extensive deltas easily accessible and typical of this form of plain, but in nearly every lake which has a stream flowing into it a more or less extensive delta may be found, and upon these it will be seen that there are very favorable conditions for marsh and swamp development.

In many places in the Southern Peninsula, clay or compact till slopes have at their tops, or superimposed upon them, sand or gravel beds, through which the water which falls as rain percolates until it reaches the clay. This it follows until it reaches the expanse of clay and running over the slopes forms a favorable place for the development of peat. Such slopes with bogs upon them occur at Ortonville in Oakland county, in the valley of Huron river, north of Ann Arbor, and at a short distance west of Chelsea, near the line of the electric railway, and in many similar places.

The northern or climbing bog has not been observed in the area studied, but the type may occur in the extreme northern end of the peninsula and has been reported from the Northern Peninsula by Shaler and others.[2]

Classification According to Method of Development.

A second method of classification of peat deposits may be based upon the way in which the deposit was developed, whether from the bottom, or the sides and top, and here again at least two main types are to be distinguished.

(C) Those built up by successive generations of plants, starting from what is now the bottom of the peat.

(D) Those which have been formed by growth at the sides, or at the top of the basin, or both.

Peat deposits of type (C) occur invariably in the shallower depressions, and upon slopes and plains, and since the depth of the water in which even aquatic plants will grow is limited to a few feet, it is evident that no deposit of peat of this kind can be more than this depth, unless from time to time the water level is raised, as the deposit is built up, or it is formed by floating aquatic plants of the higher types, or by algae.

(D) For the same reason it is clear that the filling of deep lakes with peat, so that twenty, thirty or even fifty or more feet of peat may be formed, can only take place in relatively few ways, such as: (1) The washing of dead and decaying vegetation from the shores into deeper parts of the lake basin.

(2) The drifting in of such matter from the tributary streams.

(3) Vegetation may grow out from the shores to form floating mats, which finally extend themselves to cover the entire water surface.

It is probable that it not infrequently happens that there may be filling from the sides, until the water has become shallow enough to enable water plants to attach themselves to the bottom thus formed, and from this time on, the building up from the bottom begins, although the

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[1] Geological Survey of Michigan, Vol. IX., Part I.

[2] See also Part II of this report.

development of peat from the remains of submerged aquatic plants must be very slow, because these contain such small amounts of vegetable matter relative to the semi-aquatic and land plants.

(4) In rather rare instances in the southern, and more frequently in the northern part, in small, quiet, sheltered bodies of water, floating, rootless species of plants may develop in sufficiently large numbers at and near the surface to become important factors in the work of filling the deeper parts.

Classification According to Surface Vegetation.

Still a third system of classification is frequently adopted by prospectors for peat, by botanists, and others, which, while it is purely superficial, would, in general, probably be considered as the most natural. This is based upon the kinds of plants growing upon the surface of the deposit, and the inference, which has led to much misapprehension in this respect, is that the peat below is formed by vegetation which at any given time may be growing upon its surface, and is governed by this in its character.

In giving names of this sort to peat deposits, usually some conspicuous species of plant, or sometimes more than one, gives its name to the formation, despite the fact that many others are associated with it, which may be more important as peat formers. Any classification made upon this particular basis would include at least the following types in Michigan:

(1) Elm and Black Ash[1] swamps.
(2) Tamarack swamps, marshes and bogs.
(3) Cedar (Arbor Vitæ) swamps.
(4) Spruce swamps.
(5) Willow and Alder swamps.
(6) Heath (Blue-berry, Cranberry and Cassandra) swamps, marshes or bogs.
(7) Grass and sedge marshes and bogs.
(8) Rush marshes (Cat-tail and Bullrush marshes belong here).
(9) Moss bogs (including Sphagnum bogs).

Elm and Ash swamps are among the most common types of the swamp forest of Southern Michigan and may occur in any locality where the drainage is sufficiently poor, whether peat is present or not. In fact, it is probably true that this type is less frequently found upon pure peat than upon mineral soils, but it may appear as a characteristic forest type upon the poorly drained surface of beds of peat, which have become thoroughly decomposed, and which are rich in mineral matter. Hence in river swamps and delta swamps, on shallow peat approaching muck and humus, they are common. On deeper peat they are found at intervals in the margins of the lake swamps, but there seems to be no way in which these are to be distinguished from those where the substratum of peat is very shallow.

This association of plants occurs upon peat several feet deep at Half

[1] Throughout this report, at the request of the State Geologist, and as a convenience both to printer and the general reader, English names are used for the different species, but in general in a perfectly definite sense, and a table of the latin equivalents in specific names for the English names used will be found at the end.

Moon Lake, in Seville township, T. 12 N., R. 4 W., sections 5 and 6, and at Mud Lake, in the same township, there was formerly an extensive forest of this type, now cut off, on peat more than four feet deep. Burns[1] reports elm and maple growth (in which the black ash is also an important constituent) at Dead Lake, upon from 5 to 10 feet of solid peat. A very extensive swamp of this general character occurs in sections 7 and 18 in T. 3 S., R. 4 E., in Washtenaw county, where, in places, the peat is more than three feet deep.

(2) Tamarack is a much more commonly recognized indicator of peat deposits than the elm, and is probably a much more certain one as well, especially in the southern part of its range, in Southern Michigan, but it is by no means confined to peat deposits. Throughout the morainal region, wherever there are undrained or poorly drained areas even in the lake plain, there are likely to be found tamarack swamps, and hence a few localities only need be mentioned. Near Ann Arbor the type is poorly illustrated by a small area at the First Sister Lake, three miles west of town. This has been drained and partly cleared, but north of the city a few miles are more extensive tracts about the small lakes, and in the undrained spots in the vicinity of Whitmore Lake, and from thence north on the line of the Ann Arbor R. R. to Durand, they are frequent and typical. Farther north, in Gratiot and Isabella counties, they are again numerous, and still farther north, in the vicinity of Cadillac, extensive areas are occupied by this type. In the borders of lakes the Tamarack frequently is found scattered singly or in groups over the grass and sedge marsh, and such a development is to be seen in the marshes around Lakeland, Livingston county, especially in those which lie north of the station a mile or more. In fact, it is usually true that the species spreads out into an open marshy area near which it may grow, as will be shown later, so that it may be found as a characteristic bog or marsh plant anywhere within its range, in sufficient numbers to become an important element of the vegetation.

The White Cedar, or Arbor Vitæ (*Thuja occidentalis* L.) characterizes a type of swamp which is northern in its distribution, and which has not been observed by the writer south of the central part of the state, but from northern Gratiot county north, the type occurs with great frequency in lake margins, in springy situations, and along the terraces of streams. One of the more southern points at which the type has been observed is at Riverdale, Gratiot county, where such a swamp formerly occupied a sloping terrace at the foot of a gravelly moraine. The accumulation of peat here was small. At Lake Orion, in Oakland county, is another southern locality for this characteristic species, where it occurs in association with the Tamarack and the Black Spruce. This illustrates a fact which should be constantly borne in mind, namely, that while any of these species may occur without admixture of others, in swamps which they characterize, they also frequently are found in mixed associations, so that a tamarack swamp may be a spruce or a cedar swamp as well, or even an ash swamp.

As one proceeds northward, the cedar swamp is more and more of common occurrence, and may indicate extensive peat deposits, or may not. At Hobart, in Wexford county, peat was more than 20 feet deep under

[1] Burns, G. P., Formation of Peat in Dead Lake, Mich. Acad. of Science, 6th report, 1905.

a heavy growth of cedar, while at Littlefield Lake, in Isabella county, the peat, under equally good growth, was, in places, less than two feet deep, and nowhere more than four feet in depth.

Spruce (*Picea Mariana and Picea brevifolia* Peck) swamps, like the cedar swamps, are of more northern distribution in the Lower Peninsula than the Tamarack swamps, but they extend somewhat further south than those characterized by the Cedar, occurring in southern Livingston and northern Washtenaw counties, either as pure spruce swamps or as those in which there is a mixture of Spruce and Tamarack. Such a mixed type occurs at Mud Lake, a mile and a half west of Whitmore Lake, where both Spruce and Tamarack are scattered over a considerable area of deep peat upon the north side of the swamp, while the Spruce is nearly entirely wanting on the south side. In the region farther north, Isabella county and northward, Spruce swamps are of more frequent occurrence and are more dense, while in the Northern Peninsula extensive areas of this type are characteristic features of the greater part of the Peninsula.

In the southern part of the area under consideration, the Willow swamp, or marsh, is a common type. In this the ground is more or less densely covered by shrubby Willows of various species, often accompanied by Poplars, the growth reaching a height of from five to twenty feet, or more. The growth may be very dense upon moderately well-drained peat or may be scattered upon that which is wet. The Willow swamp frequently borders a grass marsh, and the relationship is a genetic one, as will be pointed out below. Small Willow swamps are common over the greater part of the area studied, and are often found occupying the swampy areas along streams where there is little, if any, peat. The Alder swamp is much like the Willow swamp, except that it is usually more densely covered by the bushes, and that these grow to a greater height, and also is more northern in its region of frequent occurrence. Like Willows, the Alder is frequently the dominant growth in the wet valleys of streams, and in the region north of the central part of the Lower Peninsula, Alder swamps are very common, and may develop where there is considerable depth of peat. At Mud Lake, mentioned above, is a considerable area of Willow swamp near the western end of the peat deposit, which has accumulated there.

Alder is the characteristic shrub in a large peat swamp near Half Moon Lake in Gratiot county, and is generally a more or less important constituent of the flora of swamps along streams in the region to the north of the center of the Lower Peninsula, as well as in the other types of swamps. The chief species of Alder found in the Alder swamps of this range is *Alnus incana* (L.) Willd., and while both Willows and Alders may grow in any wet open situation, they frequently grow upon the deepest peat. These plants frequently follow clearing, draining, burning or destruction by floods of other types of vegetation.

Another type of bush cover upon peat deposits, and the one which is more likely to indicate peat of considerable depth in the Southern Peninsula of Michigan than any other kind of woody growth, is that formed by the members of the Heath family, of which the Blueberries, *Vaccinium corymbosum* L., and other species of the same genus are the best known representatives. Heath swamps are rare or absent over very considerable areas in the lake plain district, and in some portions of the morainal areas, but in others, and upon the till plains in the northern and north-central parts of the state, they are of rather frequent occurrence. The various heaths are usually associated with the moss *Sphagnum*, and the locations cited below will usually serve for both types. The association is not invariable, however, and some of the heaths have been found in extensive tracts where little, if any, *Sphagnum* was present, as on sections 25 and 26 in Dexter township, Washtenaw county (T. 1 S., R. 4 E.). Heath swamps are illustrated by a portion of the swamp about Mud Lake, already referred to, by a number of areas between Perry and Lansing, along the line of the Grand Trunk R. R., by several examples near Vestaburg in Montcalm county, in the southwest part of T. 12 N., R. 5 W., and by others in the vicinity of Boyce Lake, Roscommon county, in T. 21 N., R. 3 W. Often with the heaths will be found other shrubs, which, in the southern part of the state, may be quite as conspicuous, or even more so, but for which it does not seem necessary to make a special class here.

The grass and sedge types of marsh or bog are well known and are often called "hay marshes," because they are cut for hay. The prevailing vegetation is grass-like and may be either sedges or grasses or mixtures of the two types, although frequently there are practically no species of one or the other of the two present in quantity. Generally the sedges are found upon rather wetter situations than the grasses, but both grow finely upon peat. The wide "prairies" of Saginaw and Bay counties, extending up into Tuscola and Huron are chiefly sedge marsh, in which various species of *Carex* are the most conspicuous plants, but in the same region there are numerous limited tracts in which the grasses are the chief vegetation. The marshes of the lake borders of the vicinity of Lakeland, Livingston county, and of Four Mile Lake, near Dexter, Washtenaw county, and those along the Detroit and St. Clair rivers are chiefly sedge marshes, although in most cases, all of these pass gradually into rush marshes or bogs as one goes from the shore outward to the lake or river.

As indicated in the preceding statement, the rush swamp or bog is wetter than the sedge type in the majority of cases and may be found associated with it, and, in the localities named above the rush type is found in close proximity, or even intruding upon the other. The plants taken as characterizing this wet type of marsh are the Cat-tail Flag and the Bulrush, and, as is also true of the sedge and grass marshes, both may, and often do, grow in places where there is no peat whatever, but, on the other hand, all may grow upon peat of great depth, though where these plants are present, the peat is frequently very wet and soft.

The moss bogs are those in which some species of true moss is a marked constituent of the surface cover and rarely may be the only type present. The mosses most likely to become dominant in these places are (1) in the wettest places aquatic species of *Hypnum;* (2) in somewhat dryer areas, but still very wet, *Sphagnum;* (3) in the dryest places in bogs, or after they have been drained, *Polytrichum;* or, in shady places, the high ground species of *Hypnum;* with *Polytrichum* not uncommonly occurs the lichen *Cladonia* Sp. The heath bogs mentioned above all have more or less *Sphagnum* present, while the great peat deposit at Capac was densely covered in many places by a species of *Polytrichum,* as was the bog (swamp) at Chelsea, Washtenaw county, now being developed for fuel manufacture.

In discussing these schemes of classification it is evident that if the discussion is to serve any definite purpose, the life relations of the plants concerned in the formation of peat, the principles which govern their distribution, not only areal, but also into associations, and their adaptation to environment, must be carefully considered, since in general peat deposits have been built up by the continued addition of the dead parts of plants which have lived upon the surface of the deposit, while it was being built. It must also be borne in mind that not all such plants are of equal importance as peat formers, since some of them are of less frequent occurrence, are less vigorous in growth, and because of simple structure, furnish less vegetable matter than others.

The subject of the formation of peat has been written upon frequently for more than a century, but the discussion has been carried on mainly by European writers, who have dealt with conditions existing in colder, moister and less variable climates than that of the part of Michigan which is here discussed, and the developments described are evidently quite different from those studied here.

A brief review of the literature makes this apparent, as shown by the following citations:

Geikie[1] states that "these deposits are largely due to the growth of bog mosses and other aquatic plants, which, dying in their lower parts, continue to grow upward on the same spot." "In a thick bed of peat, it is not infrequently possible to detect a succession of plant remains, showing that one kind of vegetation has given place to another during the accumulation of the moss * * * the lowest part of the peat may contain remains of reeds, sedges, and other aquatic plants which choked the lake. Higher up the peat consists almost entirely of the matted fibers of different mosses, especially of the kind known as Bog-moss or *Sphagnum*. The uppermost layers may be full of roots of different heaths which spread over the surface of the bog."

Jukes-Brown[2] makes the following statements: "In England and Europe generally, some species of moss constitutes the greater part of the mass, but elsewhere other plants contribute largely to the growth of peat. In the English Fen country, peat is chiefly formed by a moss called *Hypnum fluitans,* but in the mountain bogs of Ireland and Scotland the moss is a species of Sphagnum."

According to Sir J. Rennie,[3] many of the peat bogs or "mosses" of Europe occupy the sites of great forests, some of which have been destroyed in historic times. The fallen timber by obstructing the natural drainage, and causing the ground to become wet and marshy has conduced to the growth of mosses which produce peat.

Brown[4] states that "on the continent (of Europe), turf formation is said to be rare on calcareous and frequent on silicious bottoms, though in Ireland the rule does not hold true, probably owing to local circumstances, not permitting of the water draining away as easily as it does in a limestone country generally." Also that 'turf' (peat), has received

[1] Geikie, A., Class Book of Geology, 1890, pp. 82-88.
[2] Jukes-Brown, A. J., Hand Book of Physical Geography, 1892, p. 211.
[3] Rennie, J., Essays on Peat, p. 65.
[4] Brown, Robert, "Our Earth and Its Story," Vol. 1, 1887, pp. 60-62.

various names indicative of the plants from which it is derived, such as 'moss-turf,' 'grass turf,' 'heath turf,' 'wood turf,' etc. The Irish often speak of a 'sod' of peat."

Speaking of the peat of Lincolnshire, Wheeler[1] says: "This peat consists of the remains of mosses, water grasses, reeds, flags, and other fresh-water plants, common to ditches and ponds, the most abundant being the *Hypnum fluitans* and the *Arundo Phragmites*."

Koller[2] makes the statement that "practically all plants except the fungi may form peat, but the bog mosses are most important, as owing to their spongy nature, they tend to produce a high water level in the pond or swamp."

Of American writers upon the subject, there are two classes, those who have written as geologists and those who have described the vegetation upon the surfaces of various types of peat deposits, from the point of view of the botanist.

Desor,[3] quoting from a letter from Lesquereux, gives as the origin of Cedar swamps along the Manistique river, the following: "When a river overflows its banks, the slimy sediment is deposited, of course, at the edge of the current, and where its force ceases; and thus a ridge is formed along the banks, behind which, on the retreat of the river, there remains stagnant water. This is the origin of peat bogs. The first growth of the still water is Chara, a plant of a peculiar composition, containing a large quantity of silica, and to the decomposition of which I attribute, in a great measure, the formation of the clay found in peat bogs. * * * Next to the Chara comes the Sphagnum. To enable these plants to grow, requires only a hollow in which moisture can lodge and a few fragments of woody fiber." Here follows a discussion of the structure, and properties of Sphagnum, and the writer concludes: "Upon the basis of these facts you may easily follow the operations of nature in the formation of Cedar swamps."

"When a little water remains in a hollow and becomes saturated with humic acid by the decomposition of vegetable substances, Sphagnum immediately establishes itself. * * * As these mosses spread * * * a favorable soil is formed for the Cedars."

Lesquereux[4] later attributed the formation of peat in the Great Dismal Swamp largely to Sphagnum, an observation which later explorers[5] dispute.

The persistence of the idea which Lesquereux advocated, and which is evidently correct for northern Europe and a portion of North America, is shown by its almost universal restatement in geological text-books and by even very recent writers upon peat. This Shaler[6] says: "In the northern section of the United States, speaking of those regions in which the mean annual temperature is below 55° F., the water mosses, especially the species of *Sphagnum*, are by far the most important swamp-breeding plants. * * * Its value as a peat producer is, throughout

1 Wheeler, W. H., The Fens of S. Lincolnshire, 2nd Ed. 1896.
2 Koller, T., Die Torf-Industrie, pp. 4-5.
3 Desor, E., in Foster, J. W. & Whitney, J. D., Report on the Geology of the Lake Superior Land District, Part 2, 1851, pp. 240-242.
4 Lesquereux, L., "Torfbildung im grossen Dismal Swamp," Zeitschr. der deutschen geolog Gesellsch. IV, 1852, pp. 695-697.
5 Kearney, H., Report on the Botanical Survey of the Great Dismal Swamp Region. Cont. U. S. Nat. Herb. VI, No. 6. 1901, p. 429.
Also Shaler, N. S., Op. cit. 320-321.
6 Shaler, Op. cit. pp. 285-286.

the section within the glacial belt, probably greater than that of all the other water loving plants."

This writer, to illustrate the importance of Sphagnum as a peat producing plant, uses the diagram which we reproduce as Fig. 2—one which has been widely reproduced in text-books of geology and elsewhere. It should be noted, in connection with this classic figure, however, that conditions, such as it represents, with Sphagnum as the mat forming, lake covering plant, do not and can not occur in the region here discussed. The real relation of plants in the formation of a cover, such as is here represented, is shown in Fig. 4 of this paper.

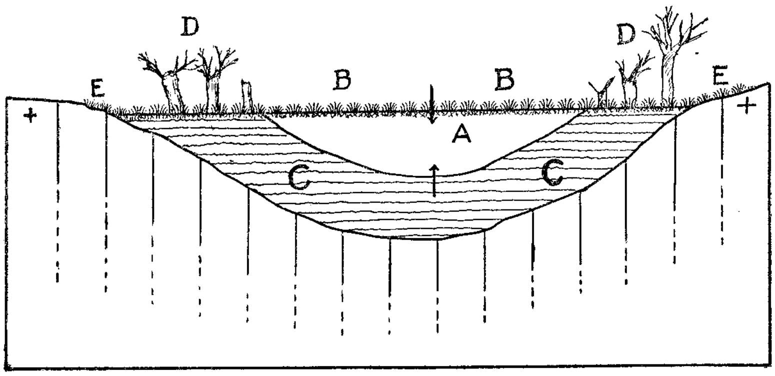

FIG. 2. Reproduced from Shaler, "Fresh-water morasses of the United States, Tenth Annual Report of the U. S. G. S., p. 257. See text and compare Fig. 4.

Dana[1] says: "In temperate climates it is due mainly to the growth of mosses of the genus *Sphagnum*."

Scott[2] has the following: "In northern regions the peat is formed principally by mosses, and especially by the bog moss *Sphagnum*. Elsewhere, as in the Great Dismal Swamp of Virginia, the leaves of trees and various aquatic plants are the sources of supply. * * * "The bogs of northern latitudes are due principally to the bog moss, *Sphagnum*, which forms dense and tangled masses of vegetation, dead and decaying below, green and flourishing above."

Tarr,[3] speaking of the filling of small lakes in the northern states, says: "One form of plant is of particular importance in this respect. A moss, the *Sphagnum*, grows luxuriantly on the shores of these tiny ponds and lakelets and by its life and death, builds a bog which is sometimes several feet in depth."

Ries,[4] in discussing the formation of peat says: "Since most peat is formed from the moss *Sphagnum* peat bogs are formed only in cold, temperate, humid climates, for the reason that *Sphagnum* does not grow in dry air, etc."

Alexander Winchell,[5] on the other hand, as early as 1860, makes the following statement: "Around the shallow margins of these lakes is

[1] Dana, J. D., Text book of Geology, 5th Ed. 1897, p. 107.
[2] Scott, B. W., Introduction to Geology, 1897, p. 133-135.
[3] Tarr, R. S., Elementary Geology, 1897, pp. 190-192.
[4] Ries, H., Op. cit. p.r 58.
[5] Winchell, A., First Biennial Report, Geological Survey of Michigan for 1860-1861, p. 130. Also see Winchell, Geological Studies, pp. 81-82.

always a belt, abounding in various forms of aquatic vegetation, which, decaying, form a deposit of vegetable matters, resting upon the marl, from the water's edge to the inner limit of vegetable growth. With the filling of the interior, the shallow belt extends towards the center and the vegetable deposit continually encroaches upon the lacustrine area until the whole lake becomes a peaty marsh."

From the botanists who have written upon the subject, a somewhat different idea of peat formation is obtained, namely, that many types of plants are concerned, especially water plants.

Cowles[1] makes this apparent in his discussion of the plant societies of the vicinity of Chicago.

Atkinson[2] intimates it in describing the "atoll moors" of the region about Ithaca, N. Y.

Mills,[3] in a recent paper, points out that "Chara, the water lilies, *Castalia* and pond lilies *Nymphaea*, are rapidly reclaiming the bottom of a small lake in Indiana.

Whitford[4] makes an equivalent statement in discussing the swamp societies of Northern Michigan.

Principles Underlying the Relation of Plants to Peat Deposits.

From these citations it would appear that the writers either had different types of formation in mind, had made merely superficial examinations or had studied the tracts which they have described as fixed phenomena. In attempting to reconcile what seem to be conflicting statements the writer began comparative studies of the flora of the peat deposits of Michigan to see if it were possible to discover any law of development by means of which a satisfactory understanding of these formations could be reached. In addition to the studies of the flora, sections of the peat were made wherever practicable, the remains of such plants as could be recognized were studied, and depth of the water level below the surface was noted, and, in many cases, the temperature of the surface and of the subsurface of the soil were taken and compared with that of the air above the surface at the same time.

The following facts were also taken into consideration, which may be stated as follows:

(1.) Relatively very few of the large and more highly organized seed plants can grow entirely submerged in water. Of the (nearly) 2,150 seed plants of Michigan but one Composite, *Bidens Beckii* Torr., a single member of the Campanulaceæ, *Lobelia Dortmanna* L., the majority of the Bladderworts, *Utricularia* species, a few of the Umbelliferæ for a portion of the season, the greater number of the Water-milfoil family, including six species of *Myriophyllum* and two of *Hippurus*, one *Proserpinaca*, and a single *Podostemon*, rarely observed have this ability. The Cruciferæ also have a single representative, *Roripa Americana* (A. Gray) Britt. The Crowfoot family is somewhat more fully represented by two species of *Batrachium*, and two of *Ranunculus*, and the Hornwort family

[1] Cowles, H. C., Op. cit. pp. 146-147.
[2] Atkinson, G. F., Elementary Botany, New York, 1898, p. 386-7.
[3] Mills, W. M., A Physiographic and ecological study of the Lake Eagle (Winona Lake) Region, Indiana, 28th report. Dept. Geol. and Nat. Res., Ind. Indianapolis, 1904, p. 380.
[4] Whitford, H. N., "The Genetic Development of the Forests of Northern Michigan." Bot. Gaz. Vol. XXXI, No. 5, May 1901, p. 313-4.
Trans. Kansas Acad. of Science, Vol. 15, 1898, p. 23.

furnishes the well-known *Ceratophyllum*. The Water Lily family sends only its leaves and flowers to the surface or slightly above it, and is an important group, having three genera and six species which may be counted as members of this class.

The Endogens furnish a much larger proportion of this type of plants, including the important *Heteranthera dubia* (Jacq.) MacM., and the members of the Naidaceæ, the Pondweed family, including *Potamogeton*, but altogether the list is a short one when compared with the total number of plants.

(2.) Of these plants which will grow in water, only a few, mainly *Potamogetons* or pond weeds, can establish themselves at a depth greater than ten feet from the surface, while the majority of submerged plants grow in less than six feet of water, unless it is unusually clear. Reed[1] reports species of *Potamogeton* reaching down into 18 feet of water, and Pieters,[2] in Lake St. Clair, found Potamogetons at about 23 feet, as the maximum depth at which any seed bearing plants occurred.

The writer has frequently tested the depth of the outer limit of the growth of the seed plants and has found it to range from 15 to 25 feet in many ponds and lakes. As this outer or deeper limit is approached the number of species is reduced. The reason for this limitation seems to be that the amount of light and heat which is available at greater depths is not sufficient for the needs of the plants.

To the plants which establish themselves in deep water must be added the Algæ, especially Chara of various species, which grow at considerably greater depths, and which, by their activities, as was pointed out by the writer[3] in previous papers, are instrumental in forming marl deposits, which raise the level of the beds of lakes, and eventually fill them.

On the other hand there are some species of plants which are able to grow luxuriantly in water in which they are unable to reach the bottom, i. e., they grow without root attachment. These are chiefly Utricularias or Bladderworts, and Myriophyllums, and they may be so abundant as to cover the entire surface of a small sheltered lake. *Utricularia vulgaris* L., has thus been noted in a number of bays and small lakes, and more rarely *U. intermedia* Hayne, and on one occasion *U. purpurea* Walt. was the species. In exposed lakes these floating plants are blown about, and are often thrown up on the shore in considerable quantities, hence in such lakes they are not usually important factors in the flora.

(3.) There are very few plants that grow partly submerged, which will grow at a depth greater than six feet, while many of this type, and among these, the most important of the peat forming species, do not grow where the water is over two feet in depth.

Among the plants which have this habitat are the cat-tail flags, *Typha*, the Bur reeds, *Sparganium*, especially *S. eurycarpum* Engelm., the Water-plantain, *Alisma plantago-aquatic* L., several Arrow-heads, *Sagittaria* species, some grasses, especially *Zizania aquatica* L., the Wild or Indian Rice, *Phragmites phragmites* (L.) Karst, Reed-grass, and *Panicularia fluitans* (L.) Kuntze, Floating Manna-grass. Among the mem-

[1] Reed, H. S., The Ecology of a Glacial Lake. Bot. Gaz. Vol. XXXIV, Chicago, 1902, p. 129.
[2] Pieters, A. J., "Plants of Lake St. Clair," Bull. Mich. Fish Commission, No. 2, 1894.
[3] Davis, C. A., Jour. Geol. 8 : 485 and 498. Also Report Mich. Geol. Survey, 8 : 66-96.

bers of the sedge family are many forms which grow in shallow water, the one which reaches the greatest depth being *Scirpus lacustris* L., the Lake Bulrush, which, in Saginaw bay, grows in water more than six feet deep. Other important plants of shallow water are species of the genera *Carex* and *Eleocharis,* also sedges. The Pickerel-Weed Family furnishes *Pontederia cordata* L., the common Pickerel weed. One other important species should be mentioned, although already listed among the wholly submerged plants, namely, the Yellow Pond Lily, *Nymphæa advena* Soland, which grows sometimes in water more than six feet deep and frequently forms very dense masses of plants of large extent, as do also the White Pond Lilies, *Castalia* sp.

(4.) Plants which grow on the dry land, or in moist soil, will rarely endure conditions where the soil is constantly saturated with water, hence they are unable to grow in such places. This seems to be due, in part at least, to the lack of available oxygen supply for the roots. A few plants growing habitually in wet places, have special adaptations to enable them to get air for their roots, and for other parts where it is needed. The best illustration of this adaptation among our native plants is found in *Decodon verticillatus* (L.) Ell. the Swamp Loosestrife in which large masses of thin walled tissue, called aerenchyma[1] develop on the stem and the pendulous branches where they come in contact with the water and apparently serve as aerating organs. The thickness diminishes above the water, the tissue changing into ordinary cortical tissue. This plant is more fully described in another section of this report. In the Tamarack a possible aerating system was observed by the writer in 1902 in the swamps where the water level was abnormally high. This consisted of very long (some a yard or more) root-like organs sent off from the older roots above the water level. Structurally these organs were composed chiefly of parenchyma and were very delicate, reddish in color and of varying thickness. Other forms of adaptation for this purpose are the large air passages which are found in the petioles of the leaves, and in the stems of the pond lilies and of many of the rushes and sedges growing in the water or in marshy soils.

(5.) In addition to the sensitiveness to lack of air in the soil, many plants are very sensitive to shading, to the presence of injurious dissolved substances, such as the ulmic, humic acids, etc., developed by the partial decomposition of vegetable matter, and to the constant low temperature about their roots, while their leaves are exposed to very varying and often high temperatures from the sun's rays.

(6.) Nearly all species of plants are affected by a change of climatic conditions, growing more vigorously in warm than in cold climates, and seem to be less sensitive to shading, as the average temperature of the growing season and also the light intensity increases.

The Formation of Peat in Depressions.

In considering these few elementary facts of plant growth in their relation to the schemes of classification given above, it is evident that depressions filled with water to a depth greater than 25 feet, would sel-

[1] Schenck, H., Ueber das Aerenchym, ein dem Kork homologes Gewebe bei Sumpf-pflanzen, Pringsheim's Jahrbucher Bd. XX, 1889.

dom or never be filled by plants of a type above the algae, growing from the bottom and gradually filling the basins by their growth and decay. Such basins must be filled either by the algae, by floating species of seed plants with no attachment to the bottom, by sedimentation from streams, by accumulation of débris from the shores, or from plant growth extending out from the shores, or by combinations of two or more of these methods. That is, in general, they are filled from the sides and top, if peat is the filling material, and the deep basin, if it were originally filled with water, must be filled in such a fashion whatever its origin, under such conditions as prevail in Michigan.

Formation of Peat in Shallow Depressions.

(a) Making application of the principles to shallow depressions, it is apparent that if these are less than 25 feet in depth, such plants as will grow in water of that depth will establish themselves in the deepest parts, and will eventually form a slowly rising deposit upon the bottom, assisted by other sediments, which may be derived from the tributary streams or from vegetation in shallower parts of the depression. As soon as this has been raised near enough to the surface of the water to enable the shallow-water plants to grow these establish themselves, and because of their greater luxuriance of growth, and firmer tissues they build up the deposit faster, until the water surface is reached, when a still greater number of plants are able to grow. When the surface of the deposit has been raised above the water level, the conditions are again improved, and again the plants are increased in number of individuals and of species, but here a new factor in the progress of the up-building comes in, for the dead material is now brought into contact with the air, and the heat of the sun, which dry out the excess of water, permit the growth of organisms producing decay, and, when a certain amount of elevation above the water level is attained, there can be no further building up, because of the drying and the thorough decay of all the dead parts of plants which fall to the surface.

No case is ever so simple, probably, as the imaginary one just cited, because of the complications which would arise in the course of the filling from fluctuations of water level, interference with established drainage, and the slow settling of the mass of sediment as it was built up, the failure of certain species of plants to become established, and the excessive development of others, the unfavorable occurrence of certain kinds of soil at the bottom of the depression, aiding in this. Thus, in many cases, for some cause not known, Chara seems able to hold the entire bottom of the deeper types of lakes and by its growth fills them with marl, upon which the seed plants establish themselves very slowly. Such deposits are illustrated by Cedar and Marl Lakes in Montcalm county, by Mattison Lake in Gratiot county, Nich-e-waugh Lake, Sec. 25, Green Oak township, Livingston county, and Four Mile Lake in Dexter township, Washtenaw county, and many others. In these there are usually large areas of shallows upon which no vegetation appears except Chara, *Scirpus lacustris* L., the bulrush and scattering plants of some species of *Potamogeton,* frequently very much dwarfed, together with the floating *Utricularia vulgaris L.* But eventually from these plants, and by the addition of organic matter from other sources, the soil becomes less calcareous and later peaty, and then other plants appear, and filling follows the usual course. At Nich-e-waugh Lake this process is now going on around the shores and upon an island of marl upon which the water was about a foot deep in June, 1904, and which was nearly covered by a growth of *Nymphaea advena* Soland, the Nuphar or Yellow Pond Lily, with which were growing species of *Potamogeton*, *Utricularia* and *Myriophyllum* in an impure marl in which the organic matter was plainly visible. In other portions of the shallows along the margin *Typha latifolia L.*, *Scripus lacustris L.*, and *Decodon verticillatus* (L.) Ell. had established themselves forming a zone shoreward from the Nuphar.

The water level of this lake was formerly higher than at present and upon the gently sloping terrace was a shallow layer of peat, upon which, and extending out into the shallow water on to the marl, were *Typha latifolia* L., forming a broad zone and in places mixed with *Phragmites Phragmites* (L.) Karst., inshore from which was an open marsh, with a shallow substratum of peat, which merged into a Tamarack swamp, where the peat was still deeper.

At Cedar Lake this process of peat formation had been developed until at the time when the land was cleared, the filled portion of the lake was occupied by a cedar swamp extending over the entire peaty area, upon which the peat was in no place more than three feet deep and usually less, while at Marl Lake, less than a mile away, there was an entire absence of peat over a great part of the marly shallows, and only very sparse vegetation, consisting chiefly of bulrushes, in a few spots upon them.

In other places, parts of the lake where the water is shallow, where there is no apparent reason for their absence, plants will not occur. The western shore of Bass Lake in Montcalm county and the northeastern shore of Whitmore Lake, in southern Livingston county as well as other parts of this lake have very few plants upon them. At Bass Lake the soil is very hard and stony which may prevent the establishment of such plants as may get a foothold, while at Whitmore Lake, the fact that the plantless area is exposed to strong winds and is sandy in consequence, may be an explanation of the lack of vegetation, since the waves created by strong winds may prevent some species from getting a start, while ice blown by the winds during the spring may tear out others which have started. A soft oozy mud bottom seems much more favorable for the growth of many types of water plants than either hard clay or shifting sands. This may be due to its more easy permeability, or to the fact that such soils are richer, which, according to Pond[1] would increase the growth of water plants.

From the foregoing it may safely be inferred that as the deposit was built up, there would be a change in the character of the vegetation as the water decreased in depth and that the plants concerned in the formation of the deposit would occupy such places as were suited to their requirements in a definite order. The same conclusion would be arrived at by studying the plant growth from the margin to the center

[1] Pond, R. H., Report U. S. Fish Commission, 1903.

of any shallow lake which is in the process of filling, for it would be found that the plants definitely arrange themselves according to the depth of the water, and if the slope of the bottom is uniform and the character of the bottom practically the same throughout, the plants of given types usually grow in well marked bands or zones, entirely around the shores. The descriptions of such lakes are numerous in botanical literature both European and American and the zonal arrangement of the plants in these locations a well recognized ecological phenomenon.

In studying a series of such lakes the conclusion must be reached that as fast as conditions are favorable, the vegetation of the shoreward zones, i. e. that growing in shallower water, moves toward the center, and is replaced by that from nearer the shore. This is due not only to the shoaling of the water and the increased light which reaches the plants growing upon the bottom, but also to increased heat, since the shallower water is more quickly warmed than the deeper, to improved aeration due to more frequent stirrings by wave and surface current-action, and to the improved physical and chemical condition of the substratum. In the majority of more than fifty small lakes and ponds studied in various parts of Michigan during the present investigation, the order of succession of seed plants was as follows: First, in the deeper water appeared the Potamogetons, often spreading over the whole central part of the lake, as in Rock Lake in Montcalm county, at a low water stage a few years ago, and several small lakes seen in Oakland county. Shoreward of this was frequently a partial or complete zone of the White or Yellow Water Lilies or both. In some small shallow ponds the Yellow Pond Lily was found covering the entire surface of the depression with no other plants visible, and at Mud Lake, Washtenaw county, both the White and Yellow Water Lilies, *Castalia tuberosa* (Paine) Greene, and *Nymphaea advena* Soland, nearly covered the surface of the remaining parts of the lake but associated with various species of Potamogeton and Utricularia. In many cases this group or zone was bordered by a wide one of the Lake Bulrush *Scirpus lacustris* L., in which were to be found on the outer margins, the plants of the outer zones, and shoreward were the sedges, or frequently, a well marked zone of *Scirpus Americanus* Pers., the "Three Square," with some other rush-like semiaquatics. At Whitmore Lake the common plant of this zone is *Eleocharis palustris*, R. & S., the Creeping Spikerush. With this, some of the sedges, various species of Carex, occur, establishing themselves above the water line, the species apparently depending upon the kind of soil and the amount of drainage, as well perhaps, as upon the accident of becoming established first.

These characteristic plants were sometimes arranged in limited areas rather than zones, or were wanting, or were replaced by other types, but they were present so often that they should be mentioned as those usually found.

The movement forward in any zone is in most cases a relatively slow one, possibly dependent upon recurring cycles of dry seasons, as is the change of condition which makes the movement possible, and on the border between two zones occurs a mixture of the characteristic plants of the two, to which the term "tension line" has been applied by various writers, in which the shoreward plants are at first in the minority, then in about equal numbers and then in the majority, as the shallow water type is generally more aggressive. Thus in those lakes where the Yellow Pond Lily is abundant, its large, thick and numerous leaves resting upon the surface or rising above it, so shut off the light, while its large rhizones and spreading roots occupy the soil below, that the submerged Potamogetons do not thrive where it is well developed and disappear when forced to compete with it, while in those lakes where the Yellow Pond Lily is absent, as at Silver Lake, Green Oak Tp., (Sec. 22, T. 1 N., R. 6 E.) the Potamogeton may occupy a much wider zone.

When the surface of the water is nearly reached by the slowly rising bottom, and the semi-aquatic types of plants give place, through the same sort of competition, to those which can live in moist soils on land, for from this time on, during some portions of some seasons, the surface of the soil is above water, and plants growing upon it must be able to accommodate themselves to this condition of variation of the water level.

Peat Formation upon Flat Areas: In applying the principles stated above to the flat, undrained areas, and to wet slopes, a slightly different set of conditions prevail, for here during a part of the year the water before peat deposition begins, may be merely sufficient to keep the soil moist or wet, while during the remainder of the time, in rainy seasons, it is possible that it may cover the surface in a thin sheet. In such cases, the conditions are much like those which exist upon the surface of a filled depression, and usually the plants which grow upon the two types of surface are identical in character and often in species. If it is assumed that the original surface was bare at the outset, such plants as will grow upon wet soils will establish themselves, and, in a relatively short time the cover of vegetation causes the drainage to become poorer, by retarding the run off. The first plants in such cases may be some species of Liverwort, like Marchantia, or of moss, like some of the Hypnums, and in cool and damp climates, of Sphagnum, while in dryer ones it may be rushes, sedges, or grasses at once. This, in turn, makes the soil still wetter, and favors the accumulation of vegetable matter in a partly decayed state upon the surface of the ground and this still more retards the flow of water, until the surface may be covered with standing or slowly moving water for a considerable portion of the year. These conditions eliminate many species of plants which may have established themselves for a time, because they are not able to live where the water level is so high, and the suppression of these sensitive forms, gives the more hardy species full opportunity, and soon the ground is all occupied by species which are adapted to the conditions. If the water level is continuously raised as the surface is elevated by vegetable accumulations, these plants will usually continue to form the dominant growth and the peat which is deposited will be made up of the remains of relatively few species and will be homogenous. The shallow beds of peat which are formed in the marshes about Saginaw Bay seem to belong to this type, the dominant plant forms being principally sedges of the genus Carex, with a few species of grasses associated with them. Certain types of terrace and valley peat deposits also belong in this group, especially those where the terrace or slope is watered by the water from seepage springs, which are constant sources of supply. These sedges, frequently *Carex stricta* Lam. are the chief surface plants of these types, and from the hygrophilous (water-loving) character of these, have probably been so from the beginning of the formation. In the northern and north central part of the Southern Peninsula, some of the mosses, not infrequently Sphagnum, may occur as a member of the surface association of plants, along with certain tree species, especially the Arbor Vitae. Such an association suggests the probability that it represents a mature condition of the deposit, in which the water level is not as high as it was in earlier states, but the type of deposit has not been carefully studied, and the series traced through.

If, however, there are periods in the growth of the deposit when the water level is rapidly raised, and remains high for a time, or is lowered and is low for a considerable period, then other types of plants establish themselves, the original flora is displaced and the deposit will take on a heterogeneous character, varying with the type of plant growth, and exhibiting well marked stratification, which makes the changes.

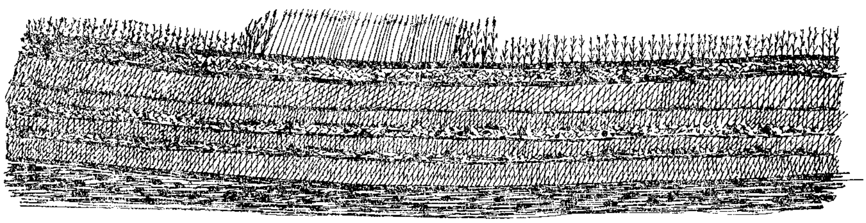

FIG. 3. Diagram showing structure of a peat bed built up from the bottom by successive elevations of water level.

Such changes may be due to the establishment of better drainage or to clogging of the drainage outlets, or to the irregular but no less potent, periodicity of rainfall and drought periods, which has been pointed out by Harrington,[1] Horton,[2] Rafter,[3] Lane[4] and others.

The accumulation of peat is a slow process, under any conditions, and during the building up of any thickness of it, there will be many periods of excessive dryness, or of great rainfall and these would inevitably cause changes in the soil, and the soil water and drainage conditions, sufficient to make radical changes in the flora, provided that they were of sufficient duration, periods of at least more than two successive years being necessary in most cases to affect a marked change.

How Depressions are Filled from the Sides and Top: The opposite extreme in the system of classification proposed above, the type of peat deposit formed by filling deep basins from the sides and top, furnishes a rather more complicated case than any of the others discussed, because here the material is accumulated in deep water, and to a considerable extent the action of the waves and currents must be taken into account.

[1] Harrington, M. W., Bulletin C, Weather Bureau, U. S. Dept. Agric. Washington, D. C.
[2] Horton, R. E., Water Supply and Irrigation Paper No. 30, U. S. G. S.
[3] Rafter, Geo. W., Water Supply and Irrigation papers, No. 80, U. S. G. S. Washingion, 1903, pp. 13-15.
Lane, A. C., Michigan Geological Survey Report, Volume VII, Part 2, pp. 38-39.

The early stages of the formation of such deposits are probably to be found in the deeper lake basins which have more or less complete zones of aquatic plants, such as those described above, and which may cover the shallower parts of the basin, as at Whitmore Lake, Half Moon Lake, and others in various parts of the state. These rings of vegetation may be broad or narrow according as the slope of the bottom is gradual or steep, and the debris from the decay of this, and such fine mineral matter as is stirred up by the waves, or is brought in by the inflowing streams, is spread over the bottom, along the surface of the vegetation zones, where it is held by the leaves, stems and roots of the plants, and in coves or indentations in the shore line, to which it is borne by the more or less constant shore currents, caused by the winds.

Such deposition as this, however, must be exceedingly slow and basins in which it is the only method show little filling, even where relatively small and shallow, as in the case of Independence Lake in Webster township, Washtenaw county, Park Lake in the same township, and Rock Lake in Montcalm county, which though in the neighborhood of filled basins have no considerable deposits of peat.

In this type of basin where filling has progressed so far that it is evident that it will soon be completed, but is still going on, the process of filling may be studied. The first marked difference between this and the type where no filling has been done, which the basin presents, is a marsh of greater or less width, the lakeward extension of which is afloat, and which is of the nature of a mat or raft, built up by the interwoven rhizomes or horizontal stems of sedges or rushes. These apparently are able to build the mat out from the shore and the filling of the water is accomplished under the margin of the mat.

Superficially the sedges resemble grasses, and in the ordinary or vegetative condition are distinguished from them mainly by having, in the kinds more important in this discussion, triangular stems, not prominently jointed nor hollow, while the grasses have hollow, jointed and round stems. In addition to these vegetative characters, the fruiting parts of the two types are very different. *Carex* is the most important genus of the sedge family, in number of species and is the one furnishing the species most efficient in the construction of mats out over the surface of the water, and of the genus, the species which in the region studied by the writer is by far the most important in this work, is *Carex filiformis* L.

This plant is not easily distinguished in the vegetative form, from other species of the same genus which grow in similar situtions, but it has very long, tough, narrow leaves, tapering to a fine thread-like point, which grow from a horizontal, subterranean or subaquatic stem, or rhizoma, from the nodes of which also grow the long slender roots. These underground stems will often grow horizontally more than a foot in length in a season, bearing at the end a terminal bud, from which new plants rise to send out in turn a new series of horizontal stems. When conditions are unfavorable for the rhizomes to grow outward into open water, they sometimes grow diagonally downward over the edge of the mat, the terminal bud developing just beyond the margin, and thus, the mat is strengthened as well as extended by the growth of the plant. These stems are tough, buoyant, and very durable, and it is by the interlacing and development of these and their roots that the mat mentioned above is built up and out over the water. Other plants of the same family, and others not related, are occasionally important in building similar structures, but the mats formed by these are not so extensive nor as firm as those built by the *Carex filiformis*.

Extensive bogs and marshes are formed by these plants by building out from the shores of lakes, the felted and interwoven mass of their submerged stems and roots making a buoyant structure capable of supporting considerable weight. It is important to note here that the sedge can, and does, grow with its rhizomes submerged a foot or more below the surface of the water, and with roots extending much farther downward.

The filling of lakes by similar developments has been described by Shaler,[1] Ries,[2] and others, but as the process as noted in Michigan, is essentially different from that described by these authors, and is of much interest and importance in the region under discussion, the following account and illustrations are given:

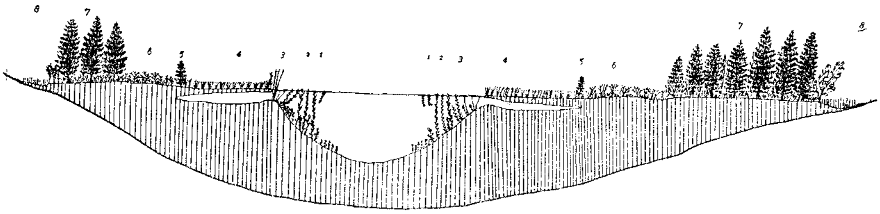

Fig. 4. Diagram showing how plants fill depressions from the sides and top.

Legend to Fig. 4.
1. Zone of Chara and floating aquatics.
2. Zone of Potamogetons.
3. Zone of Water Lilies.
4. Floating Sedge mat.
5. Advance plants of conifers and shrubs.
6. Shrub and Sphagnum zone.
7. Zone of Tamarack and Spruce.
8. Marginal Fosse.

The sedge mat being the most important and the most frequent in the region under discussion will be the one chiefly considered, and the account below will refer principally to this type.

It seems probable that the sedges are somwhat dependent upon a certain amount of preparation of the parts of the lake over which they advance, before they can proceed with their constructive work, because the margin of the mat and the water beyond it, are usually occupied by a considerable number of species of floating and submerged water plants, some of which, like the Nuphar and Potamogetons, have extensive roots and rhizomes, and require some sort of soil in which to grow. In other instances the plants along the margin of the mat are wholly unattached, such as the Bladderworts, Utricularia species.

It is possible that these plants are the pioneer forms which start the building and aid in extending the growth lakeward by furnishing a sort of substratum for the roots and rhizomes of the sedges, although in one case at least, that of Long Lake, in Fenton township, Genesee county, the rhizomes of the Carex were found extending into open water, and it

[1] Shaler. Op. cit. p.
[2] Ries. Op. cit. pp. r. 56-57.

seems certain from numerous examinations in various places that the mat gets no support from this substratum. The mat is actually floating for some distance from its outer margin, because any added weight causes it to sink rapidly, while holes through it not only end abruptly in water, but the water which pours up through these, wherever the surface is weighted down, is clear, and quite free from suspended matter. Near the lakeward edge, the mats are from a few inches at the margin, to about 18 inches or two feet in thickness back where the weight of a man may be safely borne. In a series of sections through the mat, from the water margin shoreward, the water will be found to become more and more full of finely divided matter as one proceeds toward the shore, until, at a variable distance from the water's edge the deposit is nearly solid and the mat no longer floats.

A study of the mat itself in the same sections, will show it to be of no great toughness, for holes are easily dug with the hands, but the material of which it is made is readily seen to be, in all its parts, the rhizomes and leaves of the sedges, which retain their structure and characteristics throughout the entire thickness of the mat, below which, all structure abruptly ceases, even where the mat is grounded.

This structure makes it evident that the peat deposit is not built up by the sinking of the mat under the added weight of the growth of vegetation of successive seasons, for in that case there would be a transition structure from the definitely fibrous and coherent mat, to the structureless mass below, and there would be not a space of open water between the mat and the rest of the deposit. Therefore the material which accumulates under the mat must come from the dropping down of débris from above, from the under side, and from the margins, in which case it may possibly be carried under it by some system of circulation, the causes of which need not be discussed here.

Whatever the causes of this accumulation, as the mat spreads out from the shore, at a fairly constant distance from the margin, the peat becomes rather dense and solid, so that the bog no longer floats, loses much of its quaking character and becomes firm. When this stage is reached, other plants than the sedge and the rushes begin to establish themselves upon the mat, and these eventually build up the surface, and by shading and overgrowing it destroy the sedge, which is sensitive to shading. It is possible, however, even after this has happened to show that the sedge has done its work by making a section through the superficial layers of the deposit to the level where the mat was formerly, for the remains of the rhizomes of the sedge may be found at that level in greatest abundance, as will be shown later. The peat below such a mat is usually fine grained, structureless and well decomposed, and nearly black in color.

Effects of Consolidation and Raising the Surface of the Deposit.

In no other type of peat deposit is it possible to see so clearly the marked effects which are caused by a slight change in the level of the surface, upon the flora growing above the deposit. As long as the mat is afloat the sedge is able to grow freely and keep out all competitors except such as grow in the water associated with it. Rarely the mat itself is pushed above the water level by being compacted and compressed laterally by ice thrust in the winter.

When the mat has become grounded, however, the surface is gradually built up until it is above water, at least a part of the year, and other plants appear in large numbers and in considerable variety, but always in a definite order. The number of species is not large for each level built up, but when that level has been reached, some or all of the species which should be present appear, and these, because of greater vigor in growth, in a variety of ways such as height, greater amount of foliage, and of roots, etc., usually cause the disappearance of the sedge. While the species of Carex mentioned is the most efficient and the most abundant and frequent of the genus in the sedge mats it is not the only one which is able to make extensive growths of the sort, *Carex aquatilis* Wahl., *C. Sartwellii* Dewey, and *C. utriculata* Boott, all having been noted in such mats, either alone or associated with *C. filiformis* L.

It is apparent that if the sedge mat, as long as it is afloat does not support any considerable number of other types of plants, and if the peat is gradually built up under the mat until that no longer floats, the sedge is the chief agent in forming the deposit, not even second to the water plants which grow in most cases at its outer margin. While it is not clear how the consolidation comes about, the present investigation has led to the conclusion that in no other way than that stated can the existing observed facts be accounted for, unless, as suggested above, a remarkable and not easily explained circulation exists in the water below the mat, by means of which the débris which is formed outside its edge is carried under it for considerable distances. This does not seem probable, but no final statement can be made at this time.

Among the lakes visited in which the sedge mat and attendant phenomena are well illustrated in Mud Lake[1] on the line between sections 1 and 12, Webster township, Washtenaw county, (T. 1 S., R. 5 E.). This is one of a series of depressions in a till and gravel plain lying north of Ann Arbor and bordered at the northwest by a strong moraine. These depressions are, or have been, occupied by lakes in various stages of the process of filling with peat. Of these Mud Lake is probably in the most advanced stage before the actual closing and complete covering of the waters occurs. The remaining open water is now divided by narrow strips of sedge and broken by islands of other plants, and that which would be open is well nigh covered with leaves of the pond lilies, *Castalia reniformis* (Paine) Greene and *Nymphaea advena* Soland, with *Potamogeton* of various species and other aquatics intermixed.

In the smaller holes in the sedge mat near the larger spaces of open water the *Nymphaea* is the usual lily, and associated with it are *Typha latifolia* L., the Cat-tail, growing on the shoaler places, *Pontederia cordata* L. the Pickerel-weed, and *Peltandra Virginica* (L.) Kunth., the Arrow-arum, which are able to establish themselves in water a foot or more in depth upon a very poorly compacted substratum. In places along the margins of the open pools the Lake Bulrush was present either reaching out over the lily plants or forming clumps which were minature islands and occasionally small groups of *Decodon verticillatus* (L.) Ell., the Swamp Loosestrife, grow in the margin of the sedge mat, or forming small clumps in the shallow water. These islands are evidence that the bottom of the pools is not very far from the surface

[1] Since the following account was written, a description of this locality has been printed. See Pennington, L. H., "Plant Distribution at Mud Lake." Report Mich. Acad. of Sci., Vol. VIII, 1906.

in the places in which they occur, although it may be much deeper in areas where other plants occur.

The sedge mat upon the south and east sides has a very different character upon the shoreward margin from that of the north, but upon the lakeward areas it is very similar all around to the open water except as noted below. It is wide, very wet, the sedge plants growing in from 8 to 12 inches of water, floating, so that it is strongly shaken when walked upon, and for several hundred feet back from the open water the principal plant species present is *Carex filiformis* L. with which is associated in the wettest places—often small depressions among the sedge plants—a few surviving and stunted plants of the Yellow Pond Lily, and in the water, overshaded by the sedge culms and leaves, is abundant *Utricularia intermedia* Hayne, which is a common plant also in open water as well. With this are algae, and the minute seed plants *Lemna,* frequently *L. trisulca L.*

In addition to these a more conspicuous plant was *Typha latifolia L.* which was scattered all over the marsh and entirely replaced the sedge at the east end and upon the west and northwest sides of the lake. In some places back from the edge of the mat, where the *Typha* is found in the marsh, the turf seems firmer than in others, but in general the conditions where this plant is found are quite as wet or wetter than in the pure sedge mat.

A conspicuous plant upon the sedge marsh and somewhat common with the *Typha* and one of some significance with regard to the dryness of the substratum, i. e. the height of the water level, is the Marsh Shield-fern, *Dryopteris Thelypteris* (L.) A. Gray, which, although it is found in the young stage in the western part of the sedge mat, where the sedge plants are somewhat scattered, is the dominant plant upon the areas of the mat where for some cause the surface level is very slightly higher and the turf firmer and more compact, possibly from ice thrust in the winter or the accumulation of drift material on which the sedge plants do not thrive, or are absent altogether.

This fern is very light green in color, in this kind of situation, so its position is easily seen, and it is usually accompanied by quite an extensive flora which has reached out from the more stable, open and better drained marshes near the shore, and with these, in low spots, usually are remnants of the aquatic and semi-aquatic vegetation which the sedge has not crowded out completely. The plants of this association which are from the shoreward regions, are:

Boehmeria cylindrica (L.) Willd., False Nettle. Very common.
Eupatorium purpureum L. Joe-Pye Weed.
Eupatorium perfoliatum L. Thoroughwort.
Aster junceus Ait. Rush Aster.
Lycopus communis Bicknell. Bugle-weed.
Larix Laricina (Du Roi) Koch. Tamarack.
Osmunda regalis L. Flowering Fern.
Galium spp. Bedstraw.
Triadenum Virginicum (L.) Raf. (*Elodes companulata* Pursh) Marsh St. John's wort.
Impatiens biflora Walt. Spotted Touch-me-not.
Viola alsophila Greene (*Viola blanda palustriformis,* A. Gray.) Marsh White Violet.

Carex limosa L. Mud Sedge.
Ophioglossum vulgatum L. Adder's Tongue Fern.
Limnorchis hyperborea (L.) Rydb. (*Habenaria hyperborea* R. Br.) Tall Leafy Green Orchis.

The list of those from shallow water is smaller and includes the following:

Sagittaria latifolia Willd. (*S. variabilis Engelm.*) Broad-Leaved Arrow-Head.
Peltandra Virginica (L.) Kunth. (*P. undulata* Raf.) Arrow-arum.
Typha latifolia L. (not common here.) Cat-tail.
Carex filiformis L. Slender Sedge.

This list is given because of the fact that most of the species from the shoreward group are quite constant in their association with the marsh shield fern, and, while all of them are not invariably found with it, in such places, some of them are, and they undoubtedly help prepare the surface of the sedge mat for succeeding plant associations. The Tamaracks which are found with the ferns thus far out upon the bog are usually of small size and quite young, but as soon as they get tall enough to produce shade they are accompanied by a less number of species, some of them evidently persisting from the open fern association.

Under a group of young Tamaracks, which were 8 to 10 feet in height, and formed a rather dense thicket 10 to 15 feet in diameter, somewhat farther shoreward than the most advanced stations of the ferns, the following species were found and the association is typical on this sort of growth:

Dryopteris Thelypteris (L.) A. Gray. Marsh Shield-fern.
Viola alsophila Greene. Marsh White Violet.
Onoclea sensibilis L. Sensitive Fern.
Menyanthes trifoliata L. Buck-bean.

And little else, the shade being quite dense. The *Dryopteris* in these thickets was much taller and larger and of darker green than that in the open bog.

In some of the areas of fern it was evident that another change had begun, for upon these were small and apparently recently established colonies of Sphagnum, practically the only growth of the moss upon the south and east sides of the entire marsh area. Still farther towards the shore the areas of fern were somewhat less numerous and the sedge became more dense and taller, and the surface of the marsh seemed a little lower, with more water upon it. Here the *Carex filiformis* was mixed with two other species, possibly more, but certainly with *Carex Sartwellii* Dewey, Sartwell's Sedge and some *Carex teretiuscula* Good, the Lesser-Panicled Sedge.

Here also were found associated with the sedges, more or less frequently, *Menyanthes trifoliata* L. and *Comarum* (*Potentilla*) *palustre* (L.) Marsh, the Marsh Cinquefoil.

Bordering this area and extending along the whole length of the south and east sides of the marsh was a narrow zone of shrubby willows of several species, and immediately back of this, away from the marsh, was a belt of tamaracks, several rods, or even more, in width. The plants found beneath the tamaracks which were from 20 to 40 feet in height, were as follows. In considering this list it must be remembered that the water level is below the surface of the roots of the trees, and some of the shrubs, so that these form elevated stools, covered with sufficient soil to give root-hold to various plants, hence so far as water level and drainage is concerned the species may have a considerable variety of habitat in what is often treated as a single type. No attempt is here made to indicate the water relation of the different species, although some species seemed practically confined to the low hummocks formed by roots and stumps, and others to the depressions between these; all were well within the shade of the tamaracks and were thrifty in this situation.

Woody Plants of the Tamarack Zone.

Acer rubrum, L. Red Maple.
Betula pumila L. Dwarf Birch.
Cornus stolonifera Mx. Red Osier.
Cornus candidissima Mill. Panicled Cornel, or Dogwood.
Gaylussacia resinosa (Ait.) T. & G. Huckleberry.
Ilex verticillata (L.) A. Gray. Black Alder.
Juniperus communis L. Ground Juniper.
Picea brevifolia Peck. Black Spruce.
Rhus Vernix L. (*Rhus venenata* D. C.) Poison Sumach.
Rosa Carolina L. Swamp Rose.
Rubus Americanus (Pers.) O. A. F. Dwarf Raspberry.
Solanum Dulcamara L. Wild Potato. Nightshade.
Ulmus Americana L. White Elm.
Oxycoccus Macrocarpus (Ait.) Pers. (*Vaccinium Macrocarpon* Ait.) Large Cranberry.

The Maples, Elms and Spruces were all small, the shrubs mostly well developed plants, but not old or large. Of herbs, the following list contains the most prominent species, and those which are probably most significant in the history of the development of peat.

Dryopteris Thelypteris (L.) A. Gray. Marsh Shield-fern. Here very abundant and thrifty.
Boehmeria cylindrica (L.) Willd.
Carex sterilis cephalantha Bailey. (*C. echinata cephalantha* Bailey.) Prickly Sedge.
Carex leptalea Wahl. (*C. polytrichoides* Willd.) Bristle-stalked Sedge.
Carex tenella Schk. Soft-leaved Sedge.
Carex trisperma Dewey. Three-seeded Sedge.
Coptis trifolia (L.) Salisb. Goldthread.
Equisetum fluviatile L. (*E. limosum* L.) Swamp Horsetail.
Eriophorum polystachyon L. Tall Cotton-grass.
Galium trifidum L. Small Bedstraw.

Glyceria nervata (Trin.) Nerved Manna-grass.
Panicularia nervata (Willd.) Ktze.
Impatiens biflora Walt. (*I. fulva* Nutt.) Spotted Touch-me-not.
Leptorchis Loesellii (L.) Mac M. (*Liparis Loesellii* Rich.) Fen Orchis.
Unifolium Canadense (Desf.) Greene. (*Maianthemum Canadense* Desf. False Lily-of-the-Valley.
Menyanthes trifoliata L. Buck-bean.
Osmunda cinnamomea L. Cinnamon Fern.
Osmunda regalis L. Flowering Fern.
Comarum palustre (L.) Marsh. (*Potentilla palustris* Scop.) Marsh Cinquefoil.
Rumex Brittanica L. Great Water-dock.
Sarracenia purpurea L. Pitcher-plant.
Sphagnum. This occurred sparingly in depressions below the water level.
Spathyema foetida (L.) Raf. (*Symplocarpus foetidus* Nutt.) Skunk Cabbage.
Vagnera trifolia (L.) Morong. (*Smilacina trifolia Desf.*) Three-leaved Solomon's Seal.
Viola alsophila Greene. Marsh White Violet.

Of these the *Boehmeria, Dryopteris, Osmunda, Galium, Impatiens, Menyanthes, Comarum, Sphagnum* and *Viola* are found in the preceding list, and were common in the open marsh, the *Comarum* and *Menyanthes* in the water, the others somewhat above water level. Of the other species, the *Carices* except *C. sterilis cephalantha* are species most often found in shaded swamps, often under tamaracks, and rarely in open bogs. The *Coptis* is a northern plant, found in rich woods in New England and in the Northern Peninsula and in swamps in the more southern part of its range. The *Equisetum* and *Eriophorum* are water-loving species, usually found in the open marsh, the latter often a conspicuous species in the sedge mat, but able to persist after the Tamarack has invaded this, by keeping in the more open places.

The *Galium* and *Impatiens* are plants very widely distributed in wet places, both in the open and under shade, the latter often being the only herb in the dense shade of very wet swamps.

Leptorchis, Sarracenia and *Vagnera* are plants which are usually found in peat bogs, the *Sarracenia* as frequently, or more frequently in the open than in the shade, in fact, while it will endure partial shade for a time, as this becomes more dense it seems gradually to disappear. It is frequently found growing very abundantly in deep *Sphagnum,* but may grow to perfection in wet sedge marsh, as is shown by its occurrence in many such marshes.

The *Leptorchis,* like other members of the Orchis family, is often found in the open marsh and sometimes grows perched as an epiphyte among the culms of *Carex stricta* Lam., several inches above the water.

Vagnera trifolia is, like *Coptis,* a plant of northern range, growing generally in tamarack and cedar swamps, and while it is sometimes found growing in open places where *Sphagnum* is abundant, it is more frequent in the shade and seems to need it for its best development. The Violet mentioned, the Swamp White Violet, is common in shaded wet places of various types and will grow in shade where apparently little else is found, and where the soil is very wet at certain seasons.

Of the other plants found here, the *Sphagnum* occupied the wet places, growing in the depressions between the roots of the trees and shrubs, and often in the standing water in these. More rarely it formed very small patches above the water level but it formed at the time these studies were made, no important part of the plant covering in this area. *Spathyema foetida*, the Skunk Cabbage, was much more abundant in some parts of the tamarack growth than in others, and often covered the ground entirely with its broad leaves where the soil was wet and the shade dense. It is an abundant plant in boggy and peaty soils which do not dry out, but seems to make a good growth in the beginning only under the shade of taller vegetation, but once established, it persists as long as the drainage conditions are not improved after the removal of the shade. It may establish itself at times in open springy places, where the conditions are favorable.

After passing through the belt of Tamarack just described, a second sedge marsh is passed before reaching the original shore. This, however, is gently sloping, and the surface is covered with *Carex stricta* as the most abundant plant and as this plant grows in tufts, the culms building up dense compact stools of peat, the associated plants are perched in part upon the dryer site thus afforded. The soil here is still very wet about the roots of the *Carex* until late in the summer at least, but a number of plants found here occur in the slightly dryer types of marshes, and this would indicate that the slight slope gives some drainage. Associated with the *Carex stricta* were the following species:

Cornus stolonifera Michx. Red Osier Dogwood.
Dasiphora fruticosa (L.) Rydb. (*Potentilla fruticosa* L.) Shrubby Cinquefoil.
Rhus vernix L. Poison Sumach.
Salix Bebbiana Sarg. (*S. rostrata* Rich.) Bebb's Willow, and others.
Rubus strigosus Michx. Wild Red Raspberry.
Rosa Carolina L. Swamp Rose.

These shrubs were few in number and scattered at various distances from the margin of the swamp. The herbs were the following:

Dryopteris Thelypteris (L.) A. Gray.
Boehmeria cylindrica (L.) Willd.
Geum strictum Aiton. Avens.
Solidago Canadensis L. Canada Golden-rod.
Verbena hastata L. Blue Vervain.
Lycopus Americanus Muhl. (*L. sinuatus* Ell.) Cut-leaved Water Hoarhound.
Thalictrum purpurascens L. Purplish Meadow-Rue.
Asclepias incarnata L. Swamp Milkweed.
Aster puniceus L. Purple-stem Aster.
Eupatorium purpureum L. Joe-Pye Weed.
Calamagrostis Canadensis (Mx.) Beauv. Blue. Joint.
Iris versicolor L. Blue Flag.
Asclepias Syriaca L. (*A. Cornuti* Dec.) Common Milkweed.
Potentilla Monspeliensis L., (*P. Norvegica* L.) Rough Cinquefoil.

The appearance of *Calamagrostis Canadensis* in this area marked a definitely lower water level during the growing season in the places where it was found than do the sedges.

Returning to the sedge marsh on the lakeward side of the Tamaracks, and following around to the eastward the sedge was found to be replaced by Cat-tail, *Typha*, at the east end, except in limited areas, and there were indications that the latter was increasing the territory occupied by it, such as the presence of large numbers of young *Typha* plants among the sedge, and the close relationship of the position of the fern covered areas to that of the *Typha*. The probability that this was the case was strengthened by the fact that at Whitmore Lake within three years there has been a permanent elevation of the water level of more than a foot, and at Dead Lake a similar rise has occurred so that it is certain that one has taken place at Mud Lake, and those parts of the sedge mat which did not rise promptly with the water would become wetter than before, a condition which would favor the rapid increase of *Typha* in the vicinity of places in which it was already established. Near the Tamarack, as this part of the marsh was crossed, were a few spots where the Cassandra, *Chamaedaphne calyculata* (L.) Moench., had established itself in about the same relationship to the tamarack zone as the willows were on the south side, but it was not a marked constituent of the flora here. It was also noted that along the east end of the marsh there were numbers of young specimens of Tamarack growing with the *Typha*.

The tamarack growth surrounded the entire lake with a nearly perfect elliptical border, and as this was followed along around the east end to the north side, a very abrupt change took place in the character of the vegetation in the tamarack zone and the shrub zone immediately lakeward from it. The Tamarack became mixed with a considerable percentage of Spruce, and beneath these trees numerous shrubs occur which were not found on the south side, and the surface of the ground was covered with a heavy coating of *Sphagnum* moss. The shrub zone instead of being covered by species of *Salix* was occupied by Cassandra and other species of heaths, and extending lakeward was a dense growth of *Sphagnum* with scattering Cassandra plants, the *Sphagnum* growing sometimes in the water on the sedge mat, but not extending more than a few yards lakeward. The "islands" of fern in the sedge mat here had Cassandra and large amounts of *Typha* upon them than appeared in similar places on the south side. Considering these different associations as before, the floras of the sedge mat and the open water were practically identical to those of the south side except that *Eriophorum gracile* Koch., *Scheuchzeria palustris* L. and *Carex limosa* L. were more conspicuous, growing at the same water level with the *Carex filiformis*.

The plants characteristic of the fern islands upon the south side, here made a more definite zone, which in places was well marked a short distance lakeward of the shrub zone, which invaded it at intervals; the *Sphagnum* also often apparently found favorable conditions for growth here.

The shrub zone was, as has already been stated, characterized by Cassandra, but there were other interesting species, some of which give evidence that the marsh had not long been in possession of the shrubs. Such were:

Carex filiformis L.
Carex limosa L.
Dulichium arundinaceum (L.) Britt. (*D. spathaceum* Pers.)
Comarum palustre (L.) Marsh.
Decodon verticillatus (L.) Ell.
Eriophorum gracile Koch.
Eriophorum polystachyon L.

which were usually missing where the Cassandra was dense. The shrubby plants in this outlying Cassandra zone were few, the Cassandra constituting the great bulk of individuals, and being the most conspicuous as well, but frequently either mixed with it or in nearly pure growth, was found the Andromeda, *Andromeda Polifolia* L. (L.) Britt., while the cranberries *Oxycoccus Oxycoccus* (L.) McM. and *Oxycoccus macrocarpus* (Ait.) Pers. were noticeable upon the surface of the Sphagnum, sometimes on the lakeward side of the zone forming dense mats of their delicate vines, but they also were present among the Cassandra bushes. Here also were occasional specimens of *Sarracenia* and of various species of orchids, but none of these were important members of this association. The zone was broken for short intervals here and there by depressions below the water level, and in and around these various plants of the lakeward zones persist. An indication of the future development of the plant growth was found in the numbers of small seedlings and young specimens of the Tamarack which were to be seen among the Cassandra plants and upon the Sphagnum.

The Cassandra in much of this zone was nearly buried by the upward growth of the Sphagnum around its stems, which seemed to serve as supports for the moss. The main root system of the shrub and its underground propagating shoots were often two feet below the surface of the Sphagnum, and practically below the level of the ground water during most seasons, but as the Sphagnum surrounds the stems of the shrub, adventitious roots are developed, which, if they serve no other purpose, must increase the supply of air taken in by the plant. It is evident from this relationship of the Cassandra and the Sphagnum that the shrub must establish itself as soon as the moss or before it, since the root system is at the very bottom, and often below the moss formed peat, and a section of the bog here shows that immediately below the layer of shrub remains the characteristic structures of the sedge mat are to be easily identified.

The width of this zone, including the fern association, was only two or three rods over a large part of its length, which was an eighth of a mile or more, and it was narrower than this in places. It was bounded on the shoreward side by the tamarack zone here composed of both Tamarack and Black Spruce, *Picea brevifolia* Peck, which, as indicated above, is a very different formation from that found on the south side of the lake. Here the trees were very densely crowded in some places and scattered in others, but immediately along the border of the zone they were generally dense.

At the east end was a portion of the zone with trees which are 10 to 15 feet high, mostly Tamarack, with dead and dying Cassandra under them, the dead plants easily recognizable by their well-preserved stems.

A short distance shoreward (north) of this area was the beginning of a wide Sphagnum-Cassandra bog, which is described below.

Continuing west in the tamarack zone, from the part just described, the trees were taller and more dense, and the following plants are found growing in their shade:

Vaccinium corymbosum L. Swamp Blueberry.
Ilicioides mucronata (L.) Britton. (*Nemopanthes fascicularis* Raf.) Mountain Holly.
Aronia nigra (Willd.) Britt. (*Pyrus arbutifolia melanocarpa* Mx.) Chokeberry.
Gaylussacia resinosa (Ait.) T. & G.
Oxycoccus Oxycoccus (L.) MacM.
Oxycoccus macrocarpus (Ait.) Pers.
Rhus vernix L.
Chamaedaphne calyculata (L.) Moench. (Seldom.)
Ilex verticillata (L.) A. Gray. Winterberry.

The herbs include:

Menyanthes trifoliata L. (In wet places.)
Sphagnum.
Cypripedium acaule Ait. Stemless Ladies' Slipper.
Vagnera trifolia (L.) Morong.
Carex pauciflora Lightfoot. Few-flowered sedge and other species.
Dryopteris Thelypteris (L.) A. Gray.
Woodwardia Virginica (L.) J. E. Smith. Virginia Chain-fern.

Other species occurred, but so sparsely in the shade that they need no mention here. An interesting species, common here, is *Monotropa uniflora* L., the Corpse plant or Indian Pipe, whose saprophytic habits render it indifferent to shade.

A study of the substratum of peat in this area showed that below the Sphagnum was a stratum of woody remains and the roots of the shrubs and trees, which was about a foot thick, the lower parts of this being poorly decomposed and easily recognizable as shrub remains. There had apparently been some sinking of these upper layers of peat, for the bottom of the woody zone was, so far as could be determined, several inches below the level at which shrubs are recognizable on the lakeward zone, while the water level stands at about the same distance from the surface at any given time. Below the stratum of woody remains, at a depth of less than two feet, the top of the sedge stratum was reached, containing the characteristic and well-preserved parts of the rootstocks of *Carex* and the other plants of the sedge mat.

Following along to the west in the tamarack zone or along the marsh, about half way down the north side of the lake, the Cassandra zone was abruptly displayed by *Typha*. The Tamarack persisted in a narrow zone, but the *Typha* passed through and behind it, while from 50 to 100 feet lakeward in the *Typha* marsh were numerous young Tamaracks a few feet high. Shoreward of the Tamarack was a rather dense growth of Willows, Poplars, much *Rhus vernix* L., *Rubus strigosus* Mx. and a few young Elms, *Ulmus Americana* L., White Ashes, *Fraxinus Americana L.*, and Red Maples, *Acer rubum* L. The Sphagnum became very rare, as did the low shrubs, which, until this place was reached, had been very abundant, while *Vaccinium corymbosum* L., the Blueberry, which had been a characteristic plant, disappeared entirely. There were numerous hollows, in which water stood, and the shrubs and trees were all on the low hummocks which covered the ground between these. The shade of the woody plants was so dense that there were few herbs to be found, and the few that were present were unimportant as constituents of the association. The numerous dead tamarack poles, and the peculiarly sharp transition from one type of vegetation to the other, as well as the peculiar association of plants which existed, all pointed to some sudden and violent change of conditions, by which not only was the old vegetation entirely destroyed, but the soil and soil water relations so changed that the area could not be restocked from the unaffected part to the east, before the plants from higher ground came in and occupied the vacant space. The indications all pointed to severe fire during some dry period at no very remote date, as the agency most likely to have caused such a wholesale change and the fire marks on the tamarack stumps were additional evidence in this direction. The fire not only killed and removed the vegetation but also burned off the loose layers of vegetable débris from the top of the peat, and improved its mechanical and chemical composition and thus fitted it for the types of plants which now occupy it, but this very removal of the surface material brought the surface so much nearer the water level that the *Typha* was able to invade the area, and if any prolonged period of high water occurs the new association of plants will be destroyed and the former will then be able to close in again. This was already indicated by the presence, in the Typha marsh on the lakeward side, of young Tamaracks and patches of Cassandra, which were not losing ground in this situation.

At the west end of the lake was a sedge bog, apparently a floating mat, with *Carex filiformis* L. as the dominant plant. Shoreward were abundant *Typha* plants and many Tamaracks from 5 to 10 feet high were scattered over it.

Returning to the eastward, beyond the path of the old fire, and crossing the bog towards the north, an open Cassandra-Sphagnum tract was found. Here the principal plants were the shrubs, Cassandra and Andromeda, but Tamaracks and Black Spruces were scattered over the bog in considerable and increasing numbers, as was shown by the numerous young individuals. In addition to the trees, there were several species of tall shrubs which formed a dense growth around the borders of the Cassandra and were spreading rapidly into and over it, as could be seen in many places where the lower shrubs were already dead under the taller ones. The plants growing here were:

Vaccinium corymbosum L. Swamp Blueberry.
Vaccinium Canadense Richards. Canada Blueberry.
Vaccinium Pennsylvanicum Lam. Dwarf Blueberry.
Andromeda Polifolia L. Andromeda.
Kalmia glauca Ait. Pale Laurel. (Rare.)
Gaylussacia resinosa (Ait.) T. & G.
Ilicioides mucronata (L.) Britton. (Border.)
Aronia nigra (Willd.) Britton. (Border.)
Oxycoccus Oxycoccus (L.) McM.

Oxycoccus macrocarpus (Ait.) Pers.
Populus tremuloides Michx. American Aspen.
Picea brevifolia Peck.
Larix laricina (DuRoi) Koch.
Carex pauciflora Lightfoot.
Carex oligosperma Michx. Few-seeded Sedge.
Eriophorum vaginatum L. Sheathed Cotton-grass.
Eriophorum Virginicum L. Virginia Cotton-grass.
Scheuchzeria palustris L.
Sarracenia purpurea L.
Monotropa uniflora L.
Sphagnum.
Polytrichum.

Charred stumps and other remains of trees, mostly Tamaracks, showed that here again fire had been instrumental in removing the older vegetation, and in bringing about a renewal of former conditions by letting in the light and lowering the level of the ground.

Here, as in the Sphagnum-Cassandra zone, the Sphagnum nearly buried the shrubs Cassandra and Andromeda, but where the former was very dense, the moss does not persist, and the same was true of it under the young Spruces, where it was entirely absent in many cases but went on growing upward around the circle formed by the branches of the trees until it built up for 18 or 20 inches with a steep slope on the side under the trees, where the surface was often more than a foot lower than that outside. These banks of Sphagnum were commonly covered with the vines of the Cranberries and with Andromeda, and less frequently *Sarracenia, Cypripedium acaule* Ait., *Monotropa uniflora* L., and young Spruces grew upon them. The water level, in early summer, was above the level of the lowest parts of this area, above that in which the roots of the shrubs lie, but in dry times it gets considerably lower. At this place the indications were that the Sphagnum has built up as high as it can, when it has reached a height of about two feet above the ground water level, and in a few cases it was found that upon the top of partially dead mounds of Sphagnum, another moss, Polytrichum, had established itself. This is a dry ground type and seemed to thrive in this place, as it does upon the surface of more thoroughly decomposed peat. The fate of this Cassandra-Sphagnum bog was plainly to be read by a brief study of the area which lay between it and the higher ground to the north, for in passing across this, the margin around the bog was covered with dense growth of taller shrubs, *Vaccinium corymbosum* L., *Aronia nigra* (Willd.) Britt., *Ilicioides mucronata* (L.) Britt. and *Ilex verticillata* (L.) A. Gray. Of these, the *Aronia nigra* (Willd.) Britt., the Chokeberry, is particularly aggressive in occupying new ground or that occupied by lower plants, for it sends out long underground stems, which in turn develop vertical leafy branches, which grow up through the moss and Cassandra thickets, and, overtopping them, soon destroy them. In parts of the area to the north of the Cassandra bog, there were remnants of an old Tamarack growth under which were tall mature shrubs of most of the species mentioned above, forming a sufficiently dense shade to keep most of the ground bare except for mosses and some few small herbs. Among the Tamaracks there were also good sized trees of *Betula lutea* Michx. f., and less frequently *Acer rubrum* L. and *Populus tremuloides* Michx. In the lighter and more open places here, the following herbaceous plants were found:

Aralia nudicaulis L. Wild Sarsaparilla.
Cypripedium acaule Ait.
Unifolium Canadense (Desf.) Greene.
Woodwardia Virginica (L.) J. E. S.
Sphagnum. (In lowest wet places, in best light.)
Carex canescens L. Silvery Sedge.
Carex trisperma Dewey. Three-seeded Sedge.
Pteridium aquilinum (L.) Kuhn. (*Pteris aquilina* L.) Common Brake.
Coptis trifolia (L.) Salisb.

In addition to the shrubs, young specimens of *Betula lutea* Michx f. and *Acer rubrum* L. were common.

The peat here was of a granular structure near the surface, and is reddish brown in color. In early summer, the water stands near or at the surface of the low places and unless the season is very dry, does not get very low at any time. The top layers of peat were composed of the remains of branches, and other woody parts of trees and shrubs, with well-marked layers of leaf remains intermixed, extending down a foot or more from the surface. This layer was compact, and filled for several inches with the living roots of the trees and was coarsely granular in structure.

The peat in the Cassandra zone was much less granular, was softer and wetter, and was made up of the easily identified remains of Sphagnum for about a foot or a foot and one-half from the lowest places upon the surface. Below this was a thin stratum of shrub remains, characterized by well-preserved branches and stems of the shrubs, and under this within two feet of the surface, where the tests were made, the sedge turf was reached and abundant root-stocks and other parts of the *Carex* and accompanying plants were present and were brought to the surface.

Bordering upon this region of mature Tamaracks and covering a large part of the shoreward residue of the swamp, was a very dense growth of Poplars and Willows, interrupted frequently by shallow pools of small extent. These pools were bordered by *Typha,* various species of *Carex* and often by the low growing shrub Willows. Everywhere through this area were found the scorched remains of Tamaracks and Spruces, in many places the stumps with the roots almost entirely exposed, showing a considerable lowering of the surface level of the peat. It was evident that here again fire had changed the conditions, modified the structure of the soil and lowered its surface, and the present plant growth was of very recent origin. The presence of young Tamaracks under the Poplars was an indication that a new cycle has begun, which may eventually restore the Tamarack to its dominant position.

At the outer edge of the north side was a well-marked fosse, or marginal ditch—an open space usually covered with water from 1 to 2 feet deep, and supporting a dense growth of *Carex riparia* W. Curtis and *Typha.*

This sort of depression is nearly always present about the margins of peat deposits of this type, often extending entirely around them, and is generally wholly or partly filled with water, at least in wet seasons, and has an association of plants similar to that found here, the list of which might be considerably extended.

Similar phenomena have been discussed by McMillan,[1] who attributes the formation of Sphagnum atolls to "a season of gradual recession of the waters, followed by a season of comparatively rapid increase in area and level." Atkinson[2] attributes this ditch to the rapid and luxuriant growth of the original plants which establish themselves three or four meters from the shore and build up a deposit, from which the filling begins to work lakeward, "shutting off the shallower water near the shore from the deeper water of the pond."

In the numerous examples of this part of swamps and bogs of Michigan examined by the writer, it has seemed that the efficient cause in their production was the fluctuation of the water level through rather brief intervals and the constant recurrence of such fluctuations. These, as has already been pointed out, are attendant upon the variations in the rainfall, and the water level in the lakes, and depressions, may vary one, two, or more, feet every few years, and may remain at the low water stage for several years in succession, as has been shown is the case at Whitmore Lake, where the low water period was sufficiently long to enable young Red Cedar (*Juniperus Virginiana* L.) trees to establish themselves and reach a height of several feet on the abandoned lake bottom, before the water rose again. A similar drop in the water level took place at Rock and Bass Lakes in Montcalm county, the water being over two feet lower in 1894-1897 than in 1904. In like manner many shallow depressions which have been under cultivation during dry periods are, at the present writing, ponds. It is also a matter of observation that, during dry times, the water does disappear from these marginal ditches for long periods during the summer and fall, the bottoms becoming quite dry and this has the effect of destroying much of the hydrophytic vegetation which has established itself and also of thoroughly decomposing and disintegrating the organic matter which has accumulated during periods of high water, thus lowering the surface below that of the area directly above the zone of permanent water, which, being covered by a thicker layer of vegetable débris, is kept wet by the upward capillary movement of the water from below its surface.

Besides Mud Lake, a considerable number of other lakes were visited in which the sedge, *Typha* or similar floating mats were present, and in each of these practically the same plants were found. An interesting variant from the mat described above is that at Frain's Lakes, in Secs. 9 and 10, Superior township, Washtenaw county (Tp. 2 S., R. 7 E.) at a small pond on secton 11, Northfield township, Washtenaw county (T. 1 S., R. 6 E.), at Long's Lake, Davison township, Genesee county (T. 7 N., R. 8 E.), and in parts of other lakes visited, in which the plant making the advance from the margin was *Decodon verticillatus* (L.) Ell., mentioned as occurring at Mud Lake rather rarely. This made dense borders around the entire body of water on the two last lakes cited above, and was present upon the entire front of the advanc-

[1] McMillan, C., Geol. & Nat. Hist. Surv. of Minn. Bull. 9, Part 1, p. 13. Minneapolis, 1894.
[2] Atkinson, G. F., Op. cit. p. 389.

ing mat at Frain's Lakes. This plant is capable of forming masses of stems which bend over and root at the tips, at the same time making rather dense shade. The stools which they form are slightly higher than the water surface and such plants as can endure the shade and water, associated with the *Decodon* by establishing themselves upon these stools, and following in behind the advance of the *Decodon*, the sedges or *Typha* occupy the surface of the deposit. The *Decodon* stems die down each year and the advance of the plants at Frain's Lakes could be demonstrated by the existence of a number of concentric lines in the sedge mat, parallel to the present shore, in which there were a few plants of *Decodon*, less thrifty and smaller than those at the present water margin.[1] At Frain's Lakes the filling was in the middle of a long narrow depression, the mat having apparently built out from the north shore towards the south for a portion of the length of the valley and the rest of it, except at the east end of the east lake, is practically without any peat. The filled portion of the valley is nearly a fourth of a mile long and is, much of it, still covered by floating mat, through the lowest part of which is a channel connecting the two lakes.

Lakes with sedge mats are illustrated by the south shore of Half Moon Lake, in Gratiot county, by numerous examples in Livingston, Washtenaw, Isabella, Oakland and Ingham counties. In Roscommon and Wexford counties the localities visited were depressions which had been completely closed in, and, while it was apparent that the same plants as those noted in Mud Lake were present and had been actively engaged in the process of filling, the advanced stage of the deposits made the exact steps of the process not so apparent.

The Water Plants and Sedge in Relation to the Peat.

If the sedge or Typha mat, as long as it is afloat, does not support any considerable number of other species of plants than those making it, and these are superficial upon the surface of the mat, and if the peat is gradually built up under the mat until this no longer floats, it is evident that the sedge must be considered as the chief agent in filling in the space between the under surface of the mat and the top of whatever deposit the water plants and other agencies have formed below, unless a circulation of water below the mat brings in and deposits débris formed outside its edge. This hardly seems probable to the writer, but his investigation has not gone so far as to lead to a final conclusion. Until such a conclusion is arrived at the alternative that the completion of the filling of the area under the mat is due in part to thickening of the mat, and, in part, to material which falls from the under side of it while it is being thickened by the growth of sedge above, must be accepted.

The final stage in the filling of deep depressions is reached when the mat closes over the water surface entirely, and the water below is so filled with peat that the entire surface becomes firm. After this the surface is built up above the water level by succeeding plant societies which are represented in the zones at Mud Lake.

After the water of the entire lake has been covered it is usually diffi-

[1] For a further discussion of the importance of this plant in peat formation, see the account in Part II. of this Report.

cult to determine whether the method here described has been that by which it was accomplished or not, but if soundings show the basin to be a deep one, a vertical section will usually give proof that the sedge has been a chief factor in the later stages of lake destruction.

Following the time when sedges or other advancing plants have closed in over the surface of the open water of a lake or pond, however, the mat slowly thickens, as has already been pointed out, both by the building up of the surface, through the accumulation of vegetable débris and by the sinking of the mat, partly through the replacement of air and other gases held in the plant tissues by the water, water-logging, but more because of the increased load upon the surface, after the heavier tree associations become established. This sinking is, however, a slow process, and only goes so far as is necessary to establish equilibrium, i. e., until the mat is built up sufficiently to sustain the weight upon it. The thickness of this mat, even at its maximum development, is small relative to the entire depth of the deposit, rarely more than 3 or 4 feet, and in but a single case in the series examined, showing as much as 6 feet of material, which could be considered true mat, before the fluid, or semi-fluid, structureless peat below the mat was reached.

In considering the phenomenon of the thickening of the mat in this type of peat deposits, it is probable that in some cases there has been a gradual and permanent elevation of the water level, amounting to a foot or more, due to interference with the drainage from the basin, as the mat covers more and more of the water contained within it, and a lessened evaporation from the surface as the area of open water becomes more and more contracted by the growth of the mat. This interference with the drainage can readily be seen in most lakes with outlets, which are partly covered by sedge mats, but the difficulties in the way of securing absolute confirmation of the effects of such interference on the water-level, are such that none can be presented here.

Another factor to be considered in accounting for the thickening of these structures is the periodic elevation of the water surface due to cycles of increased rainfall, during which, for longer or shorter times the ground water level is raised, together with that of lakes, as has been pointed out in another place. While the floating mat undoubtedly rises with the water level to a considerable extent, there are parts of it which do not respond quickly to changes of level, and upon these the water is increased in depth in times of high water, so that water plants may establish themselves, and the plants already present may grow above the level at which they did before the rise occurred, thus increasing the thickness of the mat by adding to its upper layers new strata of rootstocks and roots.

It seems to be generally true, however, that whether the water has risen over the mat, or the mat has sunk below the water, the changes have gone on very slowly, often at about the rate at which the surface of the mat has been built up, since sections of these thickened surface structures show that during a large part of their history the plants forming them have been those which thrive either at or just below the water level.

The fact that many of the apparently filled lakes of Michigan have been covered by such thickened mats as those described above, rather than filled, has been discovered, to their great cost and embarrassment, by the railroads of the state and the engineers in charge of their construction and maintenance. The level, comparatively open surface of such bogs, as well as the apparent stability of the substratum offer special attractions for laying out railroad lines, which have often been irresistible to locating engineers. Apparently the errors have come from false estimates of the solidity and stability of the peat, gained by the use of inefficient sounding tools in the preliminary tests made to estimate the depth and stability of the substratum, for these tools will give samples which are very deceptive, since they generally show solid peat from all depths if they pass through a few feet of it, near the top of a deposit, bringing nothing from the fluid mass below.

This relatively thin covering stratum, usually only 3 or 4 feet thick, for a time after the line has been constructed, has borne the additional weight of grade and track and has endured the traffic, but sooner or later the track has sunk under an unusual load imposed upon it, by the passage of a heavily loaded train, or has persistently moved from its proper alignment under stress of continued use, because of the unstability of the peat substratum. Such bogs have given much trouble along the lines of the Pere Marquette, Ann Arbor, Michigan Central, Grand Trunk and other railroads in various places, and in the Northern Peninsula are still causing more or less anxiety along the lines of some of the more recently built roads.

A case notable in the annals of railroad engineering is described by Waterbury,[1] from whose paper the accompanying facts and Figs. 5 to 8 have been taken.

The road was originally built with a single track, and a large amount of timber was used to form a foundation for the roadbed, which was built above it. This is shown in Fig. 5. For a considerable time this

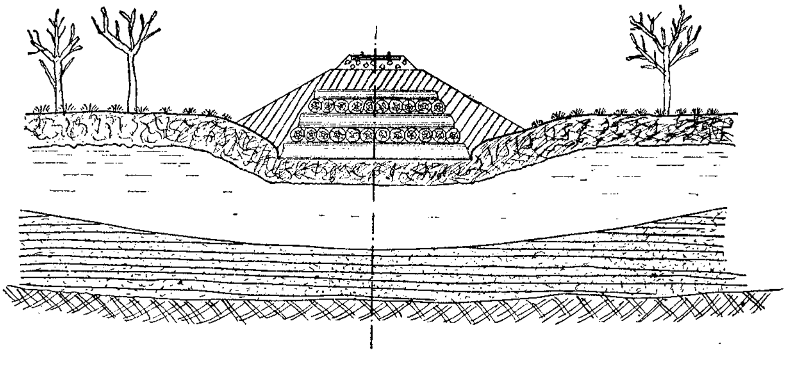

FIG. 5. Cross section showing original construction of Grand Trunk railway upon floating mat of a bog near Lansing. (Waterbury).

single track was sufficient for the needs of the road, and little difficulty was experienced from the instability of the substratum until 1902, the track was doubled. In the process of this work "the dirt, which was dumped by the side of the existing embankment, gradually sunk

[1] Waterbury, L. E., Haslett Park sink-hole on the Grand Trunk Railway. The Michigan Engineer 1903, p. 38.

out of sight, leaving a pond of water, at the same time forcing the track and right-of-way fences out of line." (Fig. 6.)

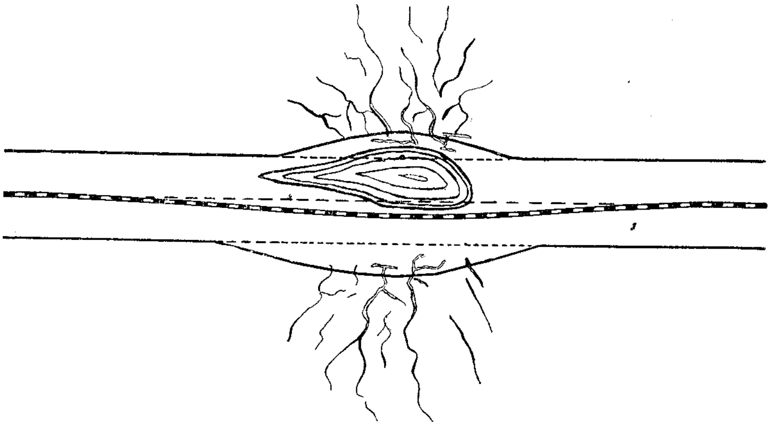

FIG. 6. Sketch map showing distortion in alignment, and cracks at sides. The dotted lines show the original positions of the fences and tracks.

The displacement of the fence was 38 feet from its original position, and of the track more than 19½ feet. The weight of the material for widening the old embankment broke the mat, carried down with it a portion of the old filling as well as the peat below it, so that the track sank whenever trains passed, sometimes a half foot, and this would have to be raised by filling before the track could be used again. In filling the opening permanently about 30,000 cubic yards of material were used before the track stopped sinking. (Fig. 7.)

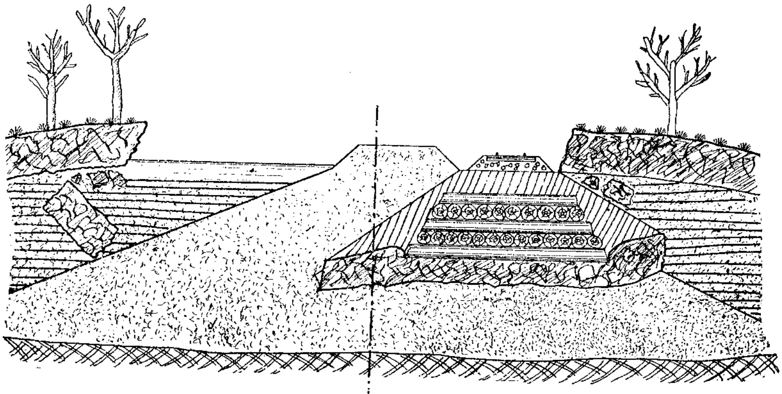

FIG. 7. Cross section, showing the displacement of the original embankment and of the floating mat, by filling for the double track.

In this figure also is shown the peculiar rising up of the mat, which amounted to at least 6 feet, caused by the displacement of water and soft peat below it, by the material used for filling.

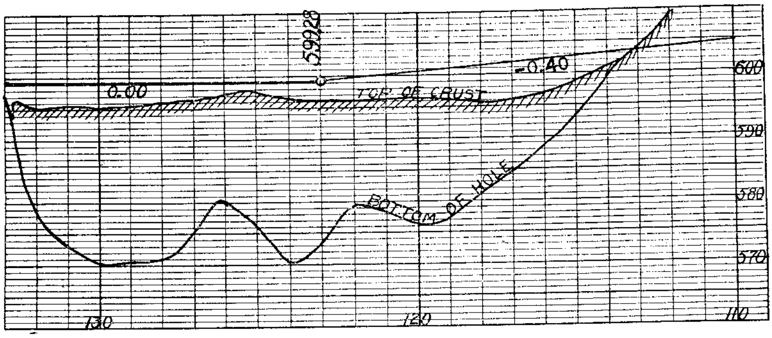

FIG. 8. Profile of a section of the bog along the line of the track. Figures on the right, elevation above the sea level.

In Fig. 8 is shown a profile of a section of the bog along the line of the track, the greatest depth being about 28 feet. In another, larger bog, on the line of the same railway, and less than 6 miles from the one described, there were used more than 60,000 cubic yards of filling in making the changes from single to double track. This depression was 55 feet deep.

The bog at Haslett Park was visited by the writer in June, 1905, and while considerable change had taken place in the vicinity of the sink-hole as described above, the elevated portions of the mat were still 4 feet above the water level, the shrinkage being in part due, in all probability, to the drying of the peat and to a certain extent, also, to changes of water level.

The surface of the bog was covered by the remnants of a forest of broad-leaved trees, mixed, in places, with *Larix laricina* (Du Roi) Koch, Tamarack, especially near the place where the sinking of the track had occurred. The following broad-leaved species of trees and shrubs were noted here:

Ulmus Americana L. White Elm.
Quercus macrocarpa Michx. Bur Oak.
Quercus platanoides (Lam.) Sudw. Swamp White Oak.
Quercus rubra L. Red Oak.
Acer rubrum L. Red Maple.

and a few other species forming a partly cleared zone around the shoreward margin. In a somewhat more open area extending from the edge of this to the sink-hole were scattered young specimens of some of these species, together with larger and more mature ones of:

Larix laricina (Du Roi) Koch. Tamarack.
Populus tremuloides Michx. Common Aspen or Poplar.
Salix nigra Marsh. Black Willow.
Betula lutea Michx. Yellow Birch.
Fraxinus nigra Marsh. Black Ash.

As undergrowth appeared the shrubs:
Corylus Americana Walt. Hazelnut.
Rhus Vernix L. Poison Sumach.
Betula pumila L. Dwarf Birch.
Aronia nigra (Willd.) Britt. Choke-berry.
Rosa Carolina L. Swamp Wild Rose.

Sphagnum was found covering small areas north of the right of way of the railroad and, in spots along the recently made cut through the raised portion of the mat. Sphagnum peat formed hummocks from 1 to 3 feet high above the general surface. A section through one of these gave the following results:

Living *Sphagnum*		6 in.
Light colored, poorly decomposed moss peat with remains of shrubs and other plants....	2 ft.	
Light colored moss peat with abundant rootstocks of *Dryopteris Thelypteris* (L.) A. Gray. Marsh Shield-fern		3 in.
Below which was:		
Coarse brown peat with tree roots and stumps	2 ft.	6 in.
Shrub remains		2 in.
Finer and darker peat with sedge remains abundant	2 ft.	

In a section through the most elevated part of the upturned mat, where there was no *Sphagnum*, measured from the top to a distance of a foot below the water level, the following strata could easily be made out:

Surface litter		6 in.
Brown, coarse, poorly decomposed peat filled with tree roots and occasionally stumps...	2 ft.	3 in.
Shrub remains		3 in.
More compact darker peat with rootstocks of the Marsh Shield-fern abundant...........		2 in.
Fine grained, dark colored peat, without remains of woody plants, but quantities of sedge and Bulrush fragments.............	2 ft.	6 in.

In some parts of the cut, layers of charcoal, the evidence of former fires were noted from 1 to 2 feet below the surface of the pushed up portion of the bog. The thin strata between the shrub and sedge remains, which had masses of the characteristic and easily identified underground stems of *Dryopteris Thelypteris*, the Marsh Shield-fern, were not always present, but were found in several places in the cut.

Below the stratum of sedge remains it was not easy to determine the remaining strata because of the depth of water present, but the peat was very dark colored and had little structure, although fragments of sedge leaves and rhizomes were occasionally found.

In a mass of this sort of material, probably from a lower level than any of the sections above, seen on the south side of the electric railway and at the west end of the uplift, the fine grained, structureless character was very noticeable, yet, even in this, fragments of the characteristic sedge remains could readily be made out, although not so abundant in it as in the material in the other sections.

In a second uplift, to the east of the one described, and on the south side of the Grand Trunk Railway, the elevation was a little over 4½ feet above the water with great cracks a foot or more wide, radiating from it, to the south. A section of this uplift gave the following strata from the top down:

Litter and living plants..............	4 in.
Coarse peat with tree roots...........	2 ft. 6 in.
Shrub remains	6 in.
Fern rootstocks	2-4 in.
Sedge rootstocks, leaves, etc..........	1 ft. to 1 ft. 4 in.
Water-level, below which no examination was made.	

From these sections it is evident that in this instance the foundation of the mat was built up, as has been already shown, by the water-loving sedges, but that the upper portions had been formed largely by the woody plants, of which the trees, with their attendant plant associates, were the most important.

In these sections it will also be noted that the orderly succession of types, described as occurring on the surface of many similar localities, is here clearly recorded in the superposed layers of the mat which is the substratum of a mature swamp forest.

Succession of Plants Upon the Peat After the Grounding of the Sedge Mat.

There are certain types of plants which apparently are always ready to reach out from the dryer places, and establish themselves in the open areas which are offered by the surface of a peat deposit formed as indicated above, and whenever a change in the elevation of the surface takes place in any way they are quick to take advantage of it. Chief among the plants to appear upon the sedge mat, even before the surface has been raised above the water level are several species of aquatic and semi-aquatic mosses, the most noticeable ones belonging to the genus *Hypnum,* or more rarely, *Sphagnum.* On the first elevations, an inch or two above the surface of the water, the plants which appear first are principally herbs, the most conspicuous and generally distributed species being the Marsh Shield-fern, *Dryopteris Thelypteris,* which is usually accompanied by a considerable number of plants found with it at Mud Lake, all of which are more or less able to add to the deposit upon which they grow and build up the surface, when they, in turn, are displaced by more aggressive types.

The *Dryopteris* and its accompanying species not infrequently form well-marked zones where conditions are favorable, but they are more often found in patches, in places where drift material has lodged at high water, or in scattered small groups, or on hummocks formed by the stools of sedge, stems of *Typha,* etc.

The fern association was not always a noticeable element of the flora of the sedge mat, but as the same may be said of all other types as well, this is not significant.

Following the fern, the *Sphagnum* moss is often found encroaching upon the sedge, usually starting upon the fern "islands," so that where the fern association is well represented, all stages of its introduction are to be found. Sphagnum grows with erect, more or less branching stems, which crowd so closely together that they form a dense cover to the surface of the parts of the bog upon which they grow, the upper parts of the plant continuing to grow after the lower part is dead, and in favorable places they may build the surface up to a height of two feet or more, especially where they are associated with shrubs. Some species persist and even thrive when the mat is flooded by water. These mosses are so much more vigorous in their growth than the *Hypnums* that they are more easily seen and more generally known, and to them is frequently attributed the formation of all peat, in fact they are known as the "peat mosses." The *Sphagnums* are not invariably found in Michigan in the types of swamps under discussion, in fact they rather seldom occur in places where they might be expected, less than 30 per cent of the number of lakes, marshes and bogs visited on the course of this investigation, having any *Sphagnum,* even when other bog plants were present. The order of the appearance of the *Sphagnum* is apparently invariable, so far, at least, as the species which build the abundant surface coverings of the marshes and bogs to which they give the name are concerned, for not only does it exist in the south, as illustrated by the Mud Lake and Dead Lake developments, but in Gratiot county at Half Moon Lake, Montcalm county at the west end of Bass Lake near Vestaburg, in Wexford county, in the bog near Hobart Station, and in several localities in Roscommon county, especially near Boyce Lake in Tp. 21 N., R. 3 and 4 W., it is the invariable order of succession.

The same relationship has been noted by the writer and is shown by Whitford[1] to exist in the northern part of the state on the islands in Lake Michigan and is indicated less clearly by Coulter[2] for the same region.

At about the same time, or level, at which these mosses appear, sometimes with them, sometimes by themselves, before them, certain shrubs, and a few species of trees make their advent in sufficient numbers to give character to the vegetation.

While these may appear often as scattered individuals upon the sedge mat or with the ferns, they are there simply stragglers, but at the level slightly higher than that at which the ferns are most prominent, Willows of a number of species, a variety of heath plants, the Dwarf Birch, and other shrubs, such as *Myrica Gale* L., the Sweet Gale, and *Lonicera oblongifolia* (Goldie) Hook, the Swamp Honeysuckle, become common, make good growth and often cover the surface completely. The tree species which first establishes itself is the Tamarack, which often appears as isolated individuals on the open bog in advance of other woody species, but in denser growth is apparently restricted to the same level as the shrubs or a slightly higher one.

[1] Whitford, H. N., Bot. Gaz. 31, 1902, pp. 313-314.

[2] Coulter, S. M., An Ecological Comparison of Some Typical Swamp Areas. Rept. Mo. Bot. Gard. 15, 1904, p. 46.

Some Ecological Factors Which Control This Succession.

The plants of this association have given students of the peat bog flora much difficulty, and writers upon plant ecology have made many attempts to explain their peculiarities of structure, and to reconcile these to their habitat, but no wholly acceptable theories have yet been advanced.

The shrubs which make their appearance at the water level indicated above, have especially well-marked adaptations to reduce the transpiration of water, that is, they are xerophytes[1] or drought plants while they live under conditions where there is a large excess of water, apparently always available. Some of the adaptations found in these shrubs are thickened leaves, thick, dense cuticle, glaucous (or waxy), or, less frequently scurfy, woolly, or hairy, and, in case of *Gaylussacia*, resinous, covering for the leaves, especially on the under side and for the young twigs. The leaves are elongated or narrowly linear in form, often rolled, i. e., reduced in size, or in the case of the conifers, short needle or awl-shaped, or reduced to scales.

Schimper[2] attributes this peculiarity to impeded absorption of water by the roots, caused by the presence of humus acids in the peat. Livingston,[3] however, has pointed out that "Bog waters do not have an appreciably higher concentration of dissolved substances than do the streams and lakes of the same region," and it is therefore evident that any effects produced by the humus acids must be chemical, if they are present at all, because the osmotic effect of bog water is that of ground water generally, and will be as readily absorbed by roots.

Whitford[4] adds to the above the factor of "insufficient aeration of the soil, which prevents a healthy growth of the root system of land plants, and also bars the presence of nitrifying bacteria." Adding that "These probably bring about xerophytic structures of the plants so commonly seen in hydrophytic habitats." Cowles[5] states that N. H. Nillson attributes the differences between the hydrophytic and xerophytic swamps to differences in food supply. It has also been suggested that the differences in temperature between the water about the roots and that of the air around the foliage of the plants in the open swamps and bogs, produces a tendency to excessive transpiration accompanied by slow absorption from the soil, the roots' activity being reduced while that of the leaves is accelerated, thus producing a need of protection against the loss of water which causes the xerophytic structure mentioned.

A comparative study of the plants of this shrub society and its habitat has made the following interesting facts apparent:

1st. The area of swamps upon which these plants become dominant is fixed so that it no longer rises and falls with fluctuations of the water level of the lake, hence the water rises and falls in the peat as it does in other soils, often as much as 15 feet in peat deposits around ponds.

2nd. During periods of minimum rainfall, the water level may fall sufficiently to leave the *Sphagnum* and the upper layers of the peat very dry, sufficiently so that they will readily burn, as is shown by the

1 Schimper, Op. cit. pp. 3-17.
2 Schimper, A. F. W., Op. cit., pp. 4 and 111.
3 Livingston, B. E., Bot. Gaz. 37 : 383-385, May 1904.
4 Whitford, H. N., Op. cit. p. 314, 315.
5 Cowles, Loc. cit. pp. 75-76.

extensive areas burned over at Mud Lake and in a number of other localities visited, in which from one to three feet of peat have been burned off. These dry periods may last for several years and during their continuance the habitat is actually, not potentially, very dry.

3rd. From peat, unless thoroughly decomposed, because of its mechanical structure, it is difficult to extract water by any means except heat, the water being held in the cell and vessel cavities of the partially disintegrated vegetable matter so firmly that the strongest pressure will not force it out, beyond a certain limited amount, and centrifugal force is equally ineffective.

These facts have been established by experiments in attempting to prepare peat for fuel without heat, and make it apparent that plants growing with their roots in peat in which the water content does not approach saturation will have difficulty in extracting sufficient for their needs. In other words, peat above the water level is structurally a very dry soil. Moreover, when it is once thoroughly dry, or even only air dry, peat does not readily absorb more than a small per cent of water, and a block of the material may be exposed for days to water without becoming wet through, because certain soluble matters in it become colloidal in drying and form a nearly insoluble coating in the outer layers. This property tends to prolong the period of drought in a bog that has been dried out.

Direct experiment with plants has demonstrated the soundness of these conclusions, for as long ago as 1875, according to Warrington,[1] Heinrich[2] reported that various crop plants required much more water when grown in peat to prevent wilting than in other kinds of soils, and that in the case of the potato the amount of water required was 41.4 per cent of the weight of moist, or 70.8 per cent of dry peat. This amount is very much greater than that required in any other soil, as is shown by the following table:

Parts of Water per 100 of Dry Soil.

Type of soil.	When plants wilted.	Absorbed from moist air.
Coarse sandy soil	1.5	1.15
Sandy garden soil	4.6	3.00
Fine humus sand	6.2	3.98
Sandy loam	7.8	5.74
Calcareous soil	9.8	5.20
Peat	49.7	42.30

In experimenting with crops on peaty lands, it has been demonstrated that the peat must contain more than 60 per cent of its weight of water to yield productive crops.[3] If these results are correctly reported, it appears that peat may appear very wet, and yet contain no water which is available for plants growing in it, so that those which habitually grow at levels of peat bogs where the surface strata can dry out, must have xerophytic adaptations if the climate is such that drying out of these levels may occur. These conclusions are supported, in

[1] Warrington, R., Physical Properties of Soils, 1900, pp. 63-64.
[2] Heinrich, Jahresb. Agrik. Chem. 1875-6. p. 368.
[3] Biedermann's Central-Blatt fur Agrik. Chem. 1885, p. 279.

part at least, by the testimony of many farmers in the region under discussion, who report that crop plants suffer more severely from drought during dry times on muck or peat soils than upon other types. Experiments with our native plants have been planned to test the correctness of these conclusions, but it is too early to report upon them at this time.

(4.) Not only must perennial plants endure, from time to time, the difficulties of real drought in peat bogs, but they must also be able to stand excessive wetness about their roots for long periods and the heath plants, *Betula pumila,* and several species of *Salix* and a few others are able to do this for at least three years without being injured, for the writer has had these species under observation where the water level has been raised more than a foot above its former height upon a heath bog for that length of time, and the plants still survive in a fairly good condition, while other species, more sensitive to water, have died.

(5.) In the heath zones and heath swamps of the southern part of the Southern Peninsula of Michigan there are more species of shrubs and trees near the water level than in the north, and as the surface of the peat is drained even slightly, species of plants occupy it which never, so far as observed by the writer, are found in the same sort of habitat at the north, but grow in the dryest and poorest soils there.

A most striking example of this is *Aralia hispida* Vent., which was a common species on the peat deposit at Chelsea, now being utilized for the manufacture of fuel. Proceeding northward some species leave the peat soils entirely and are only found upon dry and poor soils, while others still remain in them but only around their borders at a well-defined distance above water level, while others still are found at the water level as far north as observed. The following notes illustrate this:

Gaylussacia resinosa is common at Ann Arbor, both in and out of the bogs, growing as freely on light sand as it does in the bogs, but not so tall.

In Gratiot county it was rare in bogs, but very common in the dryest places on poor sandy soils, while in Roscommon county it was not noted at all in the swamps although very abundant as a sand plant. In Tuscola and Huron counties it occurred as a sand-dune plant. It endures shading well wherever found.

Dasiphora fruticosa (L.) Rydb., at Ann Arbor, is an occasional constituent of the open bog and marsh flora, in the heath zone, but occurs upon a very dry hillside at Lakeland and further north in Huron and Tuscola counties it was found only upon sandy shore lines; still farther north, however, it was noted in bogs, as well as on sandy soils.

Vaccinium Canadense, in the vicinity of Ann Arbor, is found usually, if not always, in the peat bogs, and in Gratiot county it is still a peat plant, but is found growing upon mineral soils in dry places as well, while in Roscommon county it is the most common sand and dry ground blueberry, covering sandy ridges and flats, wherever the ground was open enough, and was not listed from the peat bogs at all.

Vaccinium Pennsylvanicum does not occur in the lists made by the writer about Ann Arbor, except at Mud Lake, as noted above. At Alma, Gratiot county, it is found upon the dry and sandy knolls, but sometimes in the margins of swamps as well. In Roscommon county it occurs on dry sand commonly and was not noted elsewhere.

Vaccinium corymbosum. In Southern Michigan wherever found is a plant of the heath association, often in the very wet part of the swamps, and persisting after the surface gets quite dry, and also under the shade of the taller shrubs and trees. At Alma it is still a plant of the same association, and was not seen in the bogs examined farther north, but in New England it grows commonly on high and dry ground as well as in the swamps.

Aronia arbutifolia and *A. nigra* (Willd.) Britt., the latter more frequently, grow very commonly and with great luxuriance in many of the heath swamps in Washtenaw and Livingston counties. In Gratiot county the latter species occurred both in the peat and on dry sandy soils, and in Roscommon county it covered the sandy hillsides from the top down nearly to the water level, but was not recorded in the swamps, except as a straggling plant in the dryer parts.

Ilicioides mucronata (L.) Britton, is always a plant of the heath swamps about Ann Arbor, so far as observed, and is often found growing in very wet Tamarack swamps in the shade, to large size. At Alma it was not common, but grew in wet swamps where found. In Roscommon county it grew only on the borders of the bogs, often forming a distinct zone on the mineral soil on the borders of the bogs, from about a foot above the water level to 3 or 4 feet above it, starting in above the Cassandra. In Wexford county it was found growing in a rather dry and shallow peat deposit, near the margin.

Ilex verticillata is rather common in the vicinity of Ann Arbor, in the wet parts of peat swamps, often in the shade. It also grows well in other swamps and on mineral soils near the water level, where it endures the shade well. In Gratiot county it is very common in wooded and open swamps, and is not uncommon in the borders of swamps. In Roscommon county it was found mainly on the borders of the open swamps with *Ilicioides,* but was also found well distributed in the Cedar and Tamarack swamps, and was noted as growing from these up to a height of 3 or 4 feet above the water level on the mineral soil.

Cassandra, as found in the south, is always a plant of peat bogs and of the wettest parts of these, probably never establishing itself more than a foot above the water level, and has not been observed in the region of Ann Arbor, growing on mineral soil. In Gratiot and Montcalm counties it is usually found in the peat bogs, but at Bass Lake it grows well upon an ice-formed sand ridge at least three feet above the level of the lake, and shows in some of the bogs a tendency to grow above the water level.

In Roscommon county, while it makes luxuriant growth in the swamps and bogs, it seems to avoid the very lowest parts of these and is found making well-marked fringes around the wet sedge bogs extending out into these upon fallen logs and creeping up the sandy banks of the Sphagnum swamps, where it also covers the whole surface. It was noticed well established near Boyce Lake as much as 4 feet above the water level, growing in sand, and mixing with the Sweet Fern, which covered the higher parts of the slopes.

Kalmia glauca Ait. is a rather common plant in the region studied and associated closely with Cassandra, but was not seen outside the bogs.

Andromeda Polifolia L. is found at Ann Arbor in the wet part of the heath zone, and as far as studied shows no indication of leaving the water level or of growing in mineral soil, for in Roscommon and Wexford counties it was always found as far out in the sedge zone as any shrubby plant.

Betula pumila L., as it occurs about Ann Arbor, is common in the wet parts of the swamps and marshes in which it occurs, but persists after the water level has been lowered by draining and in a single case has been found in a moderately dry situation growing in mineral soil, at least three feet above the water level. Farther north it keeps in the peat bogs in the very wet places and does not get above the water level.

Myrica Gale L. was only found in Roscommon county growing in the wet zones of the marshes and bogs with the sedges. Farther north, however, it was seen frequently in sandy soil above the water level.

Ledum Groenlandicum Oeder, the Labrador Tea, was another species found only in the northern part of the region studied. In Hobart bog it was growing in the higher levels of the Sphagnum zone and in the tree zone, where it bore the shade well. In the vicinity of Boyce Lake it was apparently more plentiful in shade than in the open, and grew in the better drained situations slightly above the water level and sometimes in mineral soil.

Salix myrtilloides L. and *S. candida* Fl., the most interesting of the various Willows which grow in the heath swamps show little change in their relation to the water level throughout the region studied, both keeping near the water and showing no greater tendency to grow away from it at the north than at the south.

Spiraea tomentosa L., an Ann Arbor, is occasionally found growing in the peat bogs and more rarely on the wet shores of lakes, a foot or so above the level of the water. In Montcalm county this plant grows on the borders of a few bogs, but was not found growing in them. In New Hampshire the species is frequent in dry and barren pastures, where it takes the poorest and dryest places.

The Tamarack, in the region about Ann Arbor and southward, is a bog or swamp tree, seldom occurring outside of peat deposits, and usually very near the water level. It has been planted on high ground in the city and has grown well there. In Gratiot county the tree is sometimes found on high ground around swamps, while on Mackinac Island it is found growing at all elevations and in all kinds of soil, making a fairly constant element in the second growth forest.

Enough species have been cited to show the marked tendency which these bog shrubs and trees have to leave the bogs for higher ground and a type of soil where the water level is low and the soil moisture scanty, and to indicate that in the more southern part of their range plants may be confined to the bog habitat and in the northern to truly xerophytic conditions on mineral soil.

From the consideration of these facts follows the conclusion that many, if not all the "bog xerophytes" of the peat swamps of Michigan are bog plants only in the southern part of their range, and that many of their obvious adaptations for protection against drought are needed in their ordinary habitat in the region of their greatest frequency and widest dispersal and these enable them to persist in bogs and swamps during constantly recurring dry periods towards the southern limits of their range.

(6.) The plants given in the above list, many of them, have fleshy fruits, which are attractive to birds, and aid in securing the dispersal of their seeds. An observer has only to visit one of these heath swamps during the time when the various fruits are ripe to see how attractive these are in color, form and size, to the fruit-eating birds, as well as to man, for a little watching will show that more than one species is at work gathering fruit. In the late summer and early fall, the migrating season, the swamps are full of birds, and flocks of robins and blackbirds may be found at work in them at almost any time, but especially in the morning and late afternoon. In fact several species make these swamps regular migration routes as they move southward, and by them the seeds are carried from north to south each season and scattered where, if conditions are favorable, they will be most likely to germinate, namely upon thoroughly moist soil in the swamps, which keeps the seed coats, already softened by passing through the digestive system of the birds from drying again. It would seem that no other factor need be considered to account for the occurrence of the great number of shrubs which characterize the heath swamps of Michigan.

(7.) With the appearance of the shrubs and trees upon the sedge marsh, another biotic factor than tolerance of water enters into the matter of deciding what types of plants will finally occupy the ground. This is the relative need of light of the various species, or their tolerance or intolerance of shade. Those plants which live from year to year grow to different heights, and the taller ones finally overtop the shorter and unless these can endure shading they must succumb. An extended series of observations upon the woody plants growing with the *Sphagnum* upon the marshes under consideration, and others as well, establishes the fact that many of the species are unable to bear a weakened light, and as soon as shade of any density develops in their habitat, they disappear and their places are taken by species which will grow in the shade. The more aggressive species, such as *Aronia nigra,* are aided by their method of propagation, a system of long underground branches sent horizontally from the parent plant in every direction and these, at their ends and along their sides, send up vertical leaf-bearing stems which soon establish themselves and make new centers of dispersal. Such species may advance as much as six feet in a season upon any of the lower shrubs like Cassandra and in a few years after becoming established hold the entire ground. The Tamarack is taller than most of the plants with which it is associated upon the marshes, hence it shades them, and, while its shade is not dense, it seems to be effectual in stopping the growth of a number of species and finally exterminates them. Cassandra is often shaded out by the Tamarack and the only record left is that which the dead and dry stems of the lesser plant give, and the partly decayed débris in the peat below. The Blueberry, *Ilex verticillata* and *Ilicioides mucronata* on the other hand, are more tolerant and often make large growth in the shade, the last named species sometimes reaching a height of 20 feet under old Tamaracks. In like manner the Black Spruce is a taller plant than its associated species, except a few trees, and makes a denser shade than the Tamarack, and under its shade few species survive, even the *Sphagnums,* which are able to get along with less light than most of the marsh plants, give way before it. Again, the Tamarack seedlings cannot grow in the shade of the Spruce, while those of the Spruce grow readily under the Tamarack, as do those of the Cedar, so that often the Tamarack lasts but a single generation, being succeeded by the more tolerant species. The Tamarack also cannot grow up in the shade of the Red Maple and Birches and other broad leaved species and if overtopped by them at any age, is generally killed, so it gives place to these species when they succeed in establishing themselves in competition with it, and it is either driven to wetter open spots farther out upon the marsh or disappears entirely.

The Tamarack will grow under the lighter shade of Poplars and Willows, and thus may succeed a growth of these species, since they do not live when shaded by it.

From the foregoing discussion it is evident that the plants upon the surface of a peat deposit are not necessarily nor usually an indication as to the character of the peat below, and in general are relatively a short time in places where they are found. In the filled basins, and in other types of peat deposit as well, the character of the vegetation is certain to change with fluctuations of water level, which may occur as the result either of prolonged drought, periods of less than normal rainfall, or periods of excessive precipitation, the latter being especially effective in causing change, because plants which may have been years in establishing themselves in places which they occupy, may be killed in a very short time of high water and the ground which they have been occupying thus be left free from growth of such species as are able to live under the new conditions.

A change in the elevation of the outlet of the basin, if one exists, will produce the same effects as the variations in precipitation, drying out if it is lowered, and flooding if raised.

If such an elevation of the water level is at all permanent, the whole cycle of plant growth may be passed through with again. Elevations of the water level from six inches to one foot are efficient in producing complete change in some of the swamp associations.

From the lateness of appearance of the *Sphagnum* moss upon the deposit made by the water plants and the Carices it is easy to see that no great thickness of peat is built up by it. The height to which this could go on is limited by the height to which the water level may be raised after the appearance of the moss, or that to which it will rise in the *Sphagnum* through capillary action. Under climatic conditions such as prevail in Michigan, this is about 2 feet and, unless the surface of the peat slowly settles as consolidation of the material below the surface goes on, the formation of the peat ceases, so far as *Sphagnum* is concerned, at that level. In the cases where this was tested, sections at Mud Lake, and at Oxford, Oakland county, show that in less than two feet all of the deposit which can be attributed to the moss is passed through. Above this deposit there may be as much as a foot of living moss, though usually less.

A section made near Vestaburg, Montcalm county, through an island of *Sphagnum* gave 21 inches from the top of the living moss to the bottom of the moss peat, below which were 1 to 2 inches of shrub remains, probably *Cassandra,* which was still growing in the "island."

Beaver Dam near Negaunee, Mich., shows pond and marsh along border.
Photo. by Prof. R. H. Pettit, M. A. C.

Below this were remains of sedge rootstocks and roots for an inch and at from 4 to 5 inches below the bottom of the *Sphagnum* was a well marked zone an inch or more thick with large quantities of rootstocks of the Yellow Pond Lily, with numbers of the seeds in the peat above. Below this, to the bottom of the section, the peat was more homogeneous, but was easily separable into laminae, which when split apart showed large numbers of the leaves of grass-like plants.

Similar sections through the *Sphagnum* in Roscommon county, gave similar results.

Deposits Formed Behind Dams.

In the hollows which have been formed by dams of some of the types mentioned in a former paragraph, the effects of changes of the water level are shown most clearly, as in these there may be a periodical elevation of the barrier to a greater height, and this in turn holds the water impounded back to a greater height, which at once reacts upon the vegetation and changes the type of growth more or less completely.

Beaver dams were probably the most common type of dam which resulted in the formation of peat in the region of which Michigan is a part. Speaking of them and their occurrence in the state Desor[1] says: "They cite in Michigan, rivers of considerable size which are barred by dams, making thus a quantity of lakes and ponds which would not exist without them. It is evident from this that without these dams the lake and peat deposits, which are found at the bottom of these ponds, would be less numerous. The beavers have thus exercised an influence not only on the distribution of waters, and the consequent fertility of the soil but also up to a certain point even upon the distribution of recent rock formations."

The importance of the beaver as an agent in the formation of peat in the Southern Peninsula is also mentioned at some length by Bela Hubbard,[2] of the first Survey, one of the keenest writers who has ever written upon the geology and natural history of Michigan, and even earlier geologists.

In this article the writer says: "Not one or two, but a series of such dams were constructed along each stream so that very extensive surfaces became thus covered permanently with the flood. The trees were killed and the land converted into a chain of ponds and marshes with intervening dry ridges. In time, by nature's recuperative process—the annual growth of grasses and aquatic plants—these filled with muck or peat, with occasional deposits of bog lime, and the ponds and swales became dry again.

"Illustrations of this beaver-made country are numerous enough in our immediate vicinity. In a semi-circle of 12 miles around Detroit, having the river for a base, and embracing about 100,000 acres, fully one-fifth part consists of marshy tracts or prairies, which had their origin in the work of the beaver. A little further west, nearly a whole township in Wayne county is of this character."

Taking the beaver dam as an illustration, since it is small, rarely more than 5 or 6 feet high[3] and relatively rapid in its effects, the course

[1] Desor, E., La Foret Vierge, p. 57, Paris, 1879, 57.
[2] Hubbard, B., Memorials of a Half Century, pp. 362-3, N. Y., 1888.
[3] Melton and Cheadley. North West Passage by Land, p. 178.

of development of this type of peat deposit would depend upon the following considerations.

In regions of comparative flatness, the building of even a low and weak dam, such as beavers erect, will flood a considerable area. This is clearly stated by Melton and Cheadley, who report that the former operations of beavers in Canada must have been on a very extensive scale, for nearly every stream between the Pembina and the Athabasca except the large Macleod river appeared to have been destroyed by the agency of these animals.

At one place they found a long chain of marshes formed by the damming up of a stream which had ceased to exist, the beaver huts had become grassy mounds and the dam a green and solid bank.

If such an area was covered at the time when the water level was raised by a growth of trees or shrubs, these would be killed, and some would be cut down by the beavers for food and construction purposes, the rest would decay and fall to the ground or into the water, where they would shortly be overgrown and buried. The destruction of this taller growth would enable the marsh plants bordering the stream and the water plants growing in it to spread out, first upon the margins of the flooded area, then because the water is shallow, over the whole impounded surface. Such an area of shallow water would fill rapidly with vegetable débris, and as reedy and grassy types of vegetation obtained a foot-hold and became abundant the water area would be restricted, until perchance, the animals built their dam higher or abandoned it for a new place.

In the former case there would be a new advance of water plants over the marsh vegetation, while in the latter, the marsh would become at first covered with stages or *Typha* and later by grasses, one of the first to be established being probably *Calamagrostis Canadensis,* the Blue Joint, of which stages, good examples are the so-called "beaver-meadows," so often utilized as sources of hay by early settlers in Michigan and other parts of North America. At the last period as the drainage improved, Willows, Alders and other shrubs would appear on the surface and finally the forest would close in again.

The fact that the original course of the stream had been obstructed by even a weak dam would tend to cause accumulations of drift material upon the obstructed area in time of floods, and eventually this might form such a check to the drainage that the water level might be raised faster than the vegetation could build up the surface. In such a case the tree growth would be destroyed, and again the area would be covered by water and marsh vegetation, to go through the cycles as before.

In undisturbed natural conditions it is probable that the beavers would occupy a favorable site again and again as the surface of the deposit was built up and their favorite food plants re-established themselves within reach from the place where a dam could be maintained, and in at least two cases which have come to the writer's notice such dams as these have been found in cutting into peat deposits. The first of these was cut through in draining a peat bog in Sec. 2, in Arcada township, Gratiot county, where the dam was buried under about three feet of peat and seemed to be about three feet high. A case of recent reoccupation of an old dam site by a colony of beavers was observed by the writer in the Northern Peninsula, where a very old dam had been rebuilt

Beaver Meadow near Negaunee, Mich. Photo. by Prof. R. H. Pettit, M. A. C.

within the present year (1906), flooding about 50 acres of Spruce and Tamarack woods.

This dam was located in section 2, T. 49 N., R. 30 W., and was about 4 feet high in the channel of the stream which was closed by it, so that the water level was raised to that extent. The outside of the dam was a tangled mass of brush, sticks and pieces of wood both freshly cut and in all stages of decay, the animals evidently using whatever material they found near the place. The top of the dam was about a foot wide and had a number of small stones placed irregularly upon it, and the water side of the structure was heavily plastered with mud.

The dam was nearly water tight, only a small amount of water running under or through it, the greater part of that which escaped from the pond was going over the ends, which were slightly lower than the middle, or over the long side wing, built to increase the height of the water by the former tenants of the dam, and repaired by the present generation. The main structure was strong enough to bear the weight of a heavy man without yielding. The dam was built across the brook where the valley was divided by a slight elevation, and after the main part was done, the builders found it necessary to construct a long wing from the elevation across a marshy place to the other wall of the valley. This wing was from 1 to 2 feet high and about 200 feet long, and the old structure completely overgrown by shrubs and other plants, was visible, having simply been repaired in the broken places and raised in the low ones, from the pond side, by the use of small sticks and mud. The repair work was apparently very frail although fairly efficient. An interesting feature of the main dam was the fact that the arc curved irregularly down the stream. Down the same valley and extending nearly up to the dam described was a broad flat swampy area covered with shrubs and sedges, with a few scattered small trees. At the lower end of this was another ancient dam completely overgrown but easily traced as a sharp ridge across the narrow part of the valley.

Since beavers have been protected by the game laws their dams are becoming common in the wilder parts of the state and around Trout Lake Junction and other places in the Northern Peninsula, the flooding of timber lands and the destruction of trees upon them as well as the interference with railroads is reported as caused by the disturbance of the established drainage by these animals.

In draining the extensive bog at Capac, near the outlet end, or the south end of the marsh, beaver dams were cut through in making the ditches which had in the uppermost 4 feet, a second 10 feet and a third 12 feet of peat over the top, while the section of the bog in the ditches, was formed of successive and superposed layers of vegetable débris showing that several times forests had been succeeded by grass or sedge marshes. In its final stage this deposit was a Cedar and Tamarack swamp, with practically no natural outlet, the water which fell upon it either draining by seepage to the Belle river or evaporating from the surface.

At present the surface of this deposit is bare of tree growth having been denuded by fire and cutting, and while both seedling poplars and certain types of bog plants are present, the most abundant plant when visited was a species of *Polytrichum*, a moss which is usually found in bogs where the surface is very dry, and which indicates the end of peat building.

In either of the cases mentioned the resulting deposits of peat would, upon careful analysis, show a definite stratification, the strata repeating themselves in an order which would give a history of the deposit, with the remains of the more completely preserved plants identifiable. In such a deposit, at the bottom, might be found the roots and stumps of trees, above which the remains of water plants would be present to some thickness, then a mass of fibrous remains of the sedge and grasses, and possibly then the débris of mosses and shrubs, and, (showing the end of the cycle) roots, trunks and other tree débris. At Capac several strata containing tree remains were seen as noted above, but the opportunity was not offered to make a more detailed study. Where such formations of peat are found they show conclusively that the conditions under which the deposits have been formed have not been constant, but have varied, and in a definite order.

Conclusion.

The foregoing discussion makes it evident that in the Southern Peninsula of Michigan, peat is chiefly formed by plants which grow below or very near the water level, aquatic plants in connection with sedges, and other grass-like plant; *Sphagnum* does not appear until late in the history of the formation, if at all, and develops only shallow, superficial layers of peat and usually grows best in association with certain shrubs, which may become prominent before the *Sphagnum* appears, and which may also reduce its effectiveness in peat forming by developing dense shade.

The ecological factors controlling the succession of plants, which by their growth and decay, under the necessary conditions, form peat in the area under consideration have been indicated, but may be summed up as follows:

(The effects of these factors on the form of organs, i. e., adaptations, is not here considered.)

Light: That which may be considered of first importance, since a wet habitat is assumed, is the light factor, because this limits the development of peat deposits through limiting the growth of plants, both below and above the water level.

Plants which make abundant vegetative growth in northern regions must have full light, and this is not obtainable in the deeper water in depressions, or in the dense shade of other species. Direct deposition by living plants therefore is limited by the depth of water through which sufficient light may penetrate to induce vigorous plant growth, or to develop such species of plants as send leaves to the surface through earlier stages of growth, before their leaves reach the surface, and by the amount of shade in which peat-forming species can develop. The water of many lakes in the northern part of the state, while free from sediments, is dark colored from dissolved organic matter, and in such lakes there is little vegetation to be found.

Soil: A second group of factors of importance are those termed the edaphic or soil factors. Both the physical and chemical characters of the substratum in which the underground parts of plants grow are important in determining their distribution, and in many cases control the type of vegetation in a given area, or account for the presence or absence of certain types.

It seems probable, from the present state of our knowledge, that many species of the important peat-forming aquatic plants are greatly dependent upon the mechanical structure, the compactness, and the penetrability for the roots of plants, soil-water, etc., as well as the chemical composition of the soil in which they grow, and it may be demonstrated that both species and individuals are much more numerous where there are beds of loose, finely divided material, rich in plant food than where the substratum is compact, hard and poor. This is in part due to the requirements of many species for abundant food, and in part to the greater ease with which the stems and roots penetrate the less compact soils; and as the stems, or rhizomes, of a large number of such plants are propagating organs, a favorable soil for the growth of these, favors the dispersal of the species over the bottom of a lake.

Temperature: Heat is a third factor of importance, and its absence tends to reduce the number of species and number and the size of individuals, therefore in the southern part of the state many more species are found in the aquatic societies than in the northern, and these are therefore more efficient in building up peat south than north, so that it may be safely assumed that the filling of lakes goes on more slowly, and is caused by fewer plant species in the north than in the south.

The facts that the mean temperature of the air is lower during the summer season, and the periods of maximum temperature are shorter and fewer, cause decreased evaporation from wet soil and from water surfaces and render these more stable as to the water level at the north. This, because of the more uniform temperature, does not fluctuate, and changes in plant associations take place more slowly and with less frequency, north than south. The result is obvious in checking the advance of the shoreward associations to regions of high water level, since they chiefly advance in periods of low water, and in the less rapid upbuilding of the surface.

The lower soil and water temperatures at the north also tend to increase the physiological dryness of the soil in the habitat under discussion, and its physical dryness, when once dry, because the greater viscosity of water at low temperatures retards percolation and thus make it increasingly difficult for species to establish themselves in it, going from south to north.

The daily fluctuations in temperature of the air in depressions, because of lack of circulation during the day, and of the downward flow of cold air during the night, is much greater than that upon the surrounding higher lands. The minimum temperature in many of these reaches the freezing point during every month in the growing season, even in the southern part of the Southern Peninsula and this fact alone affects the composition of the associations above the sedge zone to a very considerable extent, keeping out southern plants which would otherwise establish themselves. The species near the open water of partly filled lakes or growing in it, on the other hand, probably are favored by an even temperature, and a somewhat prolonged growing season.

Air: The difficulty of getting a sufficient supply of air from soil saturated with water or from water directly, excludes from the plant associations concerned in peat formation, all plants which do not have special adaptations or cannot develop them, for the purpose of getting oxygen under the conditions presented. This limits the number of species which grow in the water, and with roots below the water level, to a few, and reduces the competition between types and species to a minimum, thus favoring good development of the types which can live under the conditions. Above the water level this factor still has its influence in excluding species which are deep rooted in favor of those which are shallow rooted, thus again reducing competition and simplifying the associations.

The other important influence of air which may be considered is in its effects as wind. In the wide stretches of open marsh or bog, plants are freely swept by winds both winter and summer, and transpiration is greatly increased thereby, a fact which again influences the composition of the plant associations growing in peat deposits with leaves exposed to the air, those which are not protected against excessive transpiration being excluded in favor of those which are, and again the composition of the associations may be simplified in number of species by this factor.

The wind, on either hand, has a profound influence in aiding in the distribution of most aquatic plants along the shores of the bodies of water in which they grow and a great many of the species of this type are provided with adaptations which insure the transportation of propagating buds, fruits and seeds from one point to another by wind and currents created by winds, and the leeward side, which is frequently the eastward one, of any body of water in which plants are growing will give numbers of illustrations of the importance of this factor.

Plants: After the length to which the subject has already been discussed it is scarcely necessary to do more than mention that the influence of most species of plants upon some of those with which they are associated is important, in a greater or less degree, according to the closeness of the association and the extent to which they have the same or similar requirements, since each species exerts some influence upon all others with which it competes for light, air, soil and water. By such competition species are eliminated from plant societies more frequently than by any other factor.

Of even more importance in affecting the composition of plant associations, and the places which these shall occupy is the influence which plants exert upon their habitat, by affecting drainage conditions as pointed out above and by concentrating mineral and other beneficial and noxious substances near the surface of the soil by their growth and decay. Each bog plant society so modifies its habitat, that sooner or later it can no longer hold it in competition with more aggressive associations and gives way before them. This modification proceeds until the rate of change produced by the plants about balances the change caused by ordinary weathering and decay, but it is of the greatest importance in considering the relations of the type of plant societies which have been under consideration.

The conclusions reached in this discussion, if valid for the region covered by the investigation, should have a much broader application than is given them, and as is shown in another paper, they have proven valid, when applied to the conditions existing in the more northern region of the Northern Peninsula of Michigan and should do so for any other.

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