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PEAT
ESSAYS ON ITS ORIGIN, USES AND DISTRIBUTION IN MICHIGAN

BY
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PART II. THE FORMATION, CHARACTER AND DISTRIBUTION OF PEAT BOGS IN THE NORTHERN PENINSULA OF MICHIGAN

BY
CHARLES A. DAVIS

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OBJECTS OF THE SURVEY.

Introduction and Acknowledgments.

On July 1st, 1905, the writer, acting under instructions received from A. C. Lane, State Geologist, a few weeks before, left Ann Arbor for Bay City, where a brief study was made of the conditions existing along the shore of Saginaw Bay a few miles north of the city, upon some interesting stages of the formation of a minor lake from a portion of the Bay, which is being cut off from the main body by bars and a long spit, built by wave and. current action aided by the growth of various plants. The lake thus formed is also being filled by the combined action of silt and the growth of water and shore plants.

This work was greatly facilitated by Mr. G. M. Bradford of Bay City, who pointed out favorable localities for study, and in other ways extended most hearty cooperation.

On July 4th Bay City was left for Frankfort, en route for Menominee, at which, place the party of Professor I. C. Russell was to be joined. Having to wait a half day for the ferry boat across to Menominee, the time was spent in the study of the relation of the vegetation to the water level along the shore of Lake Michigan and upon the high bluffs bordering the lake on the south side of the mouth of the river.

A series of very interesting facts regarding the air currents blowing from the lake, upon and around the bluffs was noted as the day was unusually favorable for making such observations. The probable bearing of these facts upon the distribution of the plants upon the bluffs is of considerable ecological interest, but the discussion of them is not germane to the subject matter in hand, so they will not be recorded here, but will form the basis of a later paper.

Menominee was reached late in the evening of July 5th and on the following day I joined Professor Russell in camp on the banks of the Menominee river, a few miles north of the city. The objects of a visit to this section of the state were several, so defined in the letters of Mr. Lane and in conversations which we had upon the subject, and these finally settled themselves in the following order.

(1.) A continuation of the study of the development and characteristics of peat bogs, begun in the Southern Peninsula two years before, to determine, if possible,

whether the principles worked out in that portion of the state were applicable throughout.

(2.) An ecological study of bogs and marshes to determine if the plants concerned in the formation of the peat were the same as those of the Southern Peninsula and also whether they followed the same succession in appearing upon the surface of the bogs, and in the swamps.

(3.) To find out the depth, degree of decomposition and the extent of the peat deposits visited, with a view to ultimate commercial utilization.

(4.) To study the distribution of the plants and plant societies which were found, to And out the zonal annuities of the flora, and in this way to gather data upon which to base a judgment as to the character and adaptability of the soil and climate to various branches of agriculture.

(5.) To examine uncut and cut-over timber land with a view to their future economic development, either for agriculture or forestry.

(6.) To note the occurrence, range and distribution of as many species of plants as it was possible to do in connection with other work.

From the outset, according to instructions, it was understood that the work which had been assigned to me was to be subordinate to that of Prof. Russell, so long as I was in his party, and that it was not in any way to hamper him nor to interfere with the general plan of his work. As the result of this understanding, the district covered by the investigation was limited, while I was with him, to that assigned to Prof. Russell.

This district, however, proved to be of great interest and gave a large number of excellent examples of various types of peat swamps, which more extended studies over wider areas, proved to be fairly representative in character, and in later studies no types were found which did not occur in this district. Aside from this it proved to be quite varied in topography and soils, so that it was possible to secure a large amount of material for the study of the general distribution of plant societies in a part of the state which has been but rarely visited by botanists, and about which little was known concerning the plant life.

The area studied while with Prof. Russell lies in the southwestern corner of the Northern Peninsula, and includes a greater part of Menominee county, and those parts of Dickinson and Iron counties which lie south of the north line of Township 42 N., and east of Range 35 W., a district which includes practically all of the settled portions of these three counties, and lies nearly all within the valley of the Menominee river, since that part of Menominee county which is drained by the Cedar river was not usually visited, although it was at times touched here and there.[1]

The excellent photographs, except those accredited to others, from which the plates accompanying this paper have been prepared, were made by Prof. I. C. Russell whose rare skill and trained judgment in selecting subjects and times for photographing, were always at the service of the writer, during a greater part of the field work on which this paper was based. The films were furnished and developed and prints were furnished by the U. S. Geological Survey, co-operating with the Michigan survey.

The writer would also acknowledge in this place, his appreciation of the unfailing patience and courtesy of Prof. Russell, who furthered in every way in his power, the special investigation of the writer, and by his kindly interest and friendly criticism, did much to increase the value of the present paper, and it is a matter of profound regret that he did not live to see the completed work.

[1]For a detailed account of this district the reader is referred to the paper by Prof. Russell in another section of this volume.

Acknowledgment is also made in this place of the obligations of the writer to Mr. Alfred C. Lane, State Geologist, for his constant and most helpful co-operation in securing material, pointing out favorable places for study, and literature relating to the region, as well as for the time spent with the writer in the field, and in other ways, while assisting in the collection of data for this work.

To Mr. Frank Leverett, of the U. S. Geological Survey, the writer would express his thanks for his kindness and assistance, during the few days spent with him, in the region between Newberry and Grand Marias.

The studies made in the Huron Mountains in 1906 were made possible by the kindness of Mr. Cyrus Bentley of Chicago, who extended to the writer the hospitality of his camp in the heart of this interesting region, and gave every facility possible for its examination. Thanks are due to him also for the illustrations from the region, Plates XXVIII A & B.

Itinerary and Area Studied

The investigation of this region was carried on in somewhat the following manner. The party, consisting of Prof. Russell, a camp keeper and cook, and myself, would fix upon a camping place from which the country around would be worked over in such a manner as the requirements of the geological work demanded, and, while this was being done, my notes and studies were made. The roads traversed were so frequently cut through standing forests, and undrained swamps, that it was not necessary to go far from them to get satisfactory opportunities to study the flora, and as a general thing much of the material gathered was picked up while the writer was accompanying Prof. Russell in his work, and it was rather infrequently the case that it was necessary to delay him or to leave him to take time for independent work, although this was at times done.

The time for which the camp was located in one place was varied from a single night to nearly a week, this depending upon the character of the country and the

quality and number of the roads which could be profitably reached from the point where the camp was placed. In all, 17 camps were made, in the 8 weeks during which I was with the party, and some of these camping places furnished most important data bearing upon the problems under investigation, and the others furnished most interesting problems in themselves, some of which still remain unsolved.

The study of the swamps and the plant societies of the uplands of this area was of such interest that it was deemed best to continue it to the limit of Prof. Russell's journey northward, especially as it was known that in the vicinity of Crystal Falls there were numerous small lakes, about which it seemed probable that a number of phases of swamp development would be found, which had not been seen so far to the north by the writer. This expectation was fully realized, and it was not until Aug. 26 that I finally left Prof. Russell in the last camp he made, at Iron River, and acting under advices recently received from Mr. Lane, I went to Bessemer by rail to make comparative studies of an extensive tract of "typical peat bog" which lies some 8 miles to the north of that city.

Leaving Bessemer on the 30th of August, I joined Mr. Lane at Hough ton on the 31st and made further comparative studies of swamps and bogs in that region, both to the south of that city, in the vicinity of the Winona mine, and to the north, in various places.

On the 5th of September, in accordance with a modification of the original tentative plan which was. made early in the season, Marquette was visited and 3 days were spent in studying the bogs and marshes along the shores of Lake Superior near that city, especially those formed behind dune lines, a phase of peat formation which I had not previously been able to carefully investigate. In each of these three regions, some attention was given to the plant societies inhabiting other types of locality than the bogs, and some valuable matter pertaining to the distribution of some of the more critical species of plants was obtained.

The final stage of the investigation was begun at Newberry, Luce county, on the 9th of September, when I joined Mr. Frank Leverett of the U. S. Geological Survey, and spent nearly a week with him in the region lying to the north and west of Newberry, and extending to the shore of Lake Superior. This region was traversed partly by driving, but chiefly by walking, and not only were a number of swamps and bogs visited, but a fine opportunity was afforded to examine a number of types of forest, and to observe the plants in the duny littoral region of Lake Superior, between the mouth of Big Two Hearted river and Grand Marais. A very short time was spent upon the shore of Grand Sable Lake and on the "Sable Banks" as the region to the west of Grand Marais is called, and a few notes upon the vegetation in that vicinity were made.

The return trip to Newberry was made in a single day and little time was available for detailed work, but the region was one of the most primitive visited, and a careful examination of it would probably lead to some very interesting results, as the hardwood forests are extensive and dense and at present very little disturbed.

A brief examination of the extensive peaty deposits in the vicinity of Newberry, yielded very little that was new, but the time available for the purpose was very short and it may be possible that a careful survey would show more that is of interest.

My return to Ann Arbor was made by the way of Trout Lake Junction and Manistique. At the former place opportunity was afforded by poor railroad connections to examine a series of swamps situated a short distance from the Junction, which had been formed between the sand ridge of the old shore line of one of the high level glacial lakes, Lake Algonquin. These swamps have been more or less frequently visited by fires and show a variety of stages of development of the surface flora.

A day was spent at Manistique in making an examination of the plant societies present upon the shores of Lake Michigan, west of Manistique and in studying the development of peat bogs between the sand dune ridges which were nearest the shore of the lake, as well as the stages by which the surface of these ridges became covered by a fixed plant population.

From Manistique, Lake Michigan was crossed to Frankfort, and again a part of a day was spent in the study of the vegetation upon the bluffs, for the sake of comparing the dominant types of herbs during the fall season with those which had been noted at previous visits to the same locality. My return to Ann Arbor was made the same day—September the 18th.

Methods of Work on Peat.

1. The plan of work adopted for the study of the peat deposits of this region was essentially that which had been used with good results in the work done in the Southern Peninsula, namely to visit as many of such deposits as possible, and examine them as thoroughly as the time at my disposal would permit: (1.) Making soundings to determine the depth and character of the peat: (2.) Noting the plants growing upon. the surface of the deposit: (3.) Studying the relation of these plants to the water level, to the peat and to each other: (4.) Making upon the surrounding flora whenever this was possible. The time at my disposal was so limited and the difficulties of traveling through the swamps were so great that it was entirely impossible to make estimates as to the area of any of the deposits covered, nor did this seem desirable in most cases.

In order to compare the genetic development of these deposits with those of the southern part of the state, and to determine the plants most important in the formation of peat it was soon found that here, as there, that it was necessary to make studies along the margins of the ponds and lakes, or in the open swamps, since the tree covered areas represented practically the end of the

cycle, that is, they were the final or climax stages in the history of the formation of the peat, and little bearing upon the problem of its development could be learned from them.

Around the open lakes, however, often a series of stages was found giving quite completely the history of the bog from the time it appeared above the surface of the water, just as has already been stated in the paper which relates to the Southern Peninsula, and it was in these open swamps that a very considerable part of my time was spent, making descriptions of the conditions existing in them.

2. On other problems. The extent of the territory visited and the brief time which could be given to any locality made the exact and detailed study and mapping the areas of any size, even in a very general way, impracticable if not impossible. After a good deal of consideration it was decided to see as much of the district as possible, and to learn what the most important types of locality and their attendant plant associations were, and then by gathering full data in a good many places where these types occurred, work out the details of the chief plant associations.

In addition to these descriptions of average conditions, all species of plants, which were only seen a few times, or but once, were recorded and notes made on their place of occurrence, abundance and habitat, as a matter of record for determining the limits of distribution, and, a considerable number of species hitherto supposed to be confined to the Southern Peninsula were thus noted.

In all cases where there was doubt as to the identity of any species which was found, specimens were collected and pressed for further study, if final determination could not be made without this, and all new records of distribution were confirmed in the same way, but no general collecting was done, because of the amount of time required for properly caring for the specimens in so moist a climate, and the difficulty of transporting the necessary presses and drying papers from camp to camp.

Types of Locality Examined.

The types of locality chosen for comparative study were (1) Swampy areas of all kinds: (2) Clay till ridges, both moraines and drumlins: (3) Band plains and ridges of a number of kinds, so far as origin goes, such as eskers, sandy moraines, etc.: (4) Outcrops of sedimentary, metamorphic and crystalline rocks: (5) Sand dunes, especially those along the shores of Lake Superior: (6) The waters of lakes and streams: (7) Cut-over lands, especially pine lands.

In making records in these types, of locality, the soil, its condition, the amount of moisture and humus, the dominant vegetation, the slope and exposure to winds, the amount of disturbance to which the vegetation had been subjected, etc., were generally taken into account and a full list of all the plants found over a considerable area was made, with notes of abundance and such other items as might help in understanding the association of species as recorded.

General Distribution of the Plants of Northern Michigan.

Making the form of the land surface, or the topography, the basis of classification there were three fairly well characterized districts in the region visited.

The first of these lay relatively near the shores of Lake Michigan and extended from Menominee well north, nearly to the iron region. This was characterized by relatively large areas of flat or slightly rolling plain, with isolated, low, long and narrow, stony clay hills, or short ridges, known as drumlins, scattered over it, either singly or in groups. In the valleys between these there were frequently found irregular, often winding, gravel or sand ridges, called eskers, which were also of no great length, a few miles at the most, and associated with them were sand and gravel knolls and hills, called kames.

Near the shore of Lake Michigan the surface was more sandy and much smoother than it was inland and had several well marked terraces at different levels above the lake, and, in places, practically continuous ridges of sand roughly paralleled with the present lake shore, which mark the shore lines of former levels of the lake and its predecessors.

The origin and nature of these types of ridges are fully discussed by Russell[1] for this region, and need no consideration here.

The drumlins were covered originally by heavy forests of mixed broad leaved species, of which the Hard Maple, Beech, Basswood, White and Rock Elms and Ironwood were the most common, with usually a considerable percent of Hemlock and scattering individuals of Balsam and White Spruce and in the northern part of the district, more or less Yellow Birch, which ultimately replaces the Beech entirely in this association a little farther to the north.

[1]Russell, I. C. A Geological Reconnaissance along the North Shore of Lakes Huron and Michigan. Annual Report, Michigan Geological Survey, 1904, pp. 65-95, Lansing, 1905. Also in this Vol., The Menominee Region.

Upon gravelly or sandy ridges, whether of the esker, the beach or the dune type, and upon sandy stream terraces and sand plains, the forest was formerly almost pure Pine, usually White Pine, but upon the lighter sands, the Norway and Jack Pines often were mixed in considerable abundance, or even formed nearly pure stands of one or the other, or of an even mixture of both species. In some areas along the Menominee river, and in other localities as well, where there was an admixture of clay and sand, or where there was a thin layer of sand over a pebbly clay loam, there were "two storied" forests, the upper story of very tall old White Pines, and the lower one of mixed broad leaved species, with Hemlock, Balsam, White Cedar, and White Spruce, as in the case

of the forests of the drumlins. In these mixtures the White Pines tower high above the other species and practically all their branches are above the top of the lower story.

Plate XVIII. Old White Pine forest with hardwood and lower growing conifers below, near Koss, on Menominee river. The forest is on the Wisconsin side of the river.

An excellent example of this type is shown in Plate XVIII, an old White Pine forest, with hard wood and lower growing coniferous trees forming the lower story, near Koss, on Menominee river. The forest is on the Wisconsin side of the river.

In this case, and in others as well, there was good White Pine reproduction, showing that the type tends to perpetuate itself.

Examples of these types are rare now, since the Pines have been cut or fires have destroyed them and the areas formerly covered by them are now growing up to Aspen, the large-toothed Poplar, Scarlet Oak, White Birch, and Red or Pin Cherry and to Sweet Fern and Bracken Fern.

The bottoms of the valleys, especially where these were poorly drained, were swamps in which Cedar or Arbor Vitae, Tamarack and Black Spruce were the most abundant tree species, although in some there were Black Ash, White Elm and Yellow Birch, usually associated with the three species first mentioned, and, much more infrequently, without them.

The second type of district, lying to the north and northwest of the first, and merging into it, may be termed the rock ridge type, in which the general surface was rather level or slightly undulating, with the relief in the form of high ridges of rock, these extending as lines of hills for miles across the country, with the flatter areas between them.

In this district the hardwood or broad-leaved type of forest was again found covering the ridges, and often the rock surface was entirely covered by thin soil, upon which, if undisturbed, was supported a fine growth of large trees. In many places, however, the timber had been cut and consequent fires, washings by rains, and denudation by the winds, had entirely removed the soil, so that the rock was quite bare, except in crevices in which grew a few stunted specimens of the more hardy trees such as the Aspen and the White Birch.

The better drained of the flatter areas here, unless sandy, were covered by hardwood forests with a mixture of Hemlock, Balsam, White Spruce and Arbor Vitae, while the terraces of the streams, sand and gravel plains, and the eskers which occurred frequently in the valleys, were formerly covered by White Pine, unless the sand was very light, when the Norway Pine took its place, and more rarely the Jack Pine. As in the former case, the pine forests have been cut, and following the cutting, the ground has been burned over again and again until there is very little Pine now on it, the only trees being the Poplars and other species mentioned in describing cut-over lands above.

In this district, the valleys were often quite extensive and well marked and the bottoms were covered by swamps, in which the same trees mentioned under this type of habitat above, were the characteristic species, and form the usual growth.

The third type of country was found to the, northward and northwestward of the other two and in it, besides the rock ridges mentioned under the second type, there were extensive ridges of bouldery clay loam or "till" similar to that which makes up the drumlins, and of the same origin, namely, deposited by the melting ice of the last glacial ice sheet, which at one time covered the whole country. The ridges under discussion were formed at the melting margin of the ice from materials which had been carried in it or were pushed up by it, and are called moraines. They were often more than a mile broad, of varying height above the rest of the country, and ran for miles across it in practically unbroken lines, while between them and the sand and gravel plains which accompany them were numerous depressions in which occur lakes of various sizes. The broad valleys between these ridges were sometimes sandy upon the sides and bottoms, but more often they were so flat as to be poorly drained and covered by swamp forests of large extent.

Extensive deposits of sand and gravel, both in the form of plains and of terraces and ridges along the sides or bottoms of the valleys were sometimes the accompaniments of the moraines.

The forests upon this type of ridge were chiefly of Hard Maple, Elm, Basswood, Yellow Birch and Black Birch, with Hemlock, Balsam, White Spruce and Arbor Vitae generally present, the latter three species as undergrowth, and in some places forming a considerable part of the timber. The Beech was not seen in this part of the area studied, being replaced by the Yellow and Black Birches. The Hard Maple was often the most important species along the tops of the moraines, making up from 50 to 70 per cent of the forest and in such places there would be no coniferous trees at all, or only a few small specimens of White Spruce or Arbor

Vitae. On the other hand on the lower slopes of the ridges and on the flat lands adjacent, if not too wet, the Hemlock and the Balsam and White Birch will be numerically in the ascendancy, and the Maples few in numbers.

Soil and Topography of the Region in Relation to the Plant Societies.

Sandy ridges, the better drained valleys with sand bottoms, and gravel and sand plains, were formerly densely stocked with pine forests, the poorest and lightest sands having chiefly Norway Pine and Jack Pine, while the better sands and the gravel supported White Pine, here as elsewhere, but they now, except in rare instances, are covered by Poplar, White Birch and other poor kinds of broad-leaved trees, little Pine of any species persisting at the present time, except where accidental isolation has preserved small numbers of individuals from destruction by the fires which followed lumbering.

The poorly drained valleys and till plains and all other places, where there was an abundant supply of water, were covered by a dense growth of Tamarack, Black Spruce, and Arbor Vitae, either growing together or quite as frequently with one or the other species predominating—the Black Spruce especially in the bogs around partially filled lakes and the Arbor Vitae mixed with the Balsam on the higher parts of swampy margins of streams and in springy places.

The Tamarack was most often found in extensive growths, forming dense, pure stands upon wet marshy tracts, either around lakes, in swampy valleys, or in any poorly drained place not already covered by other dense tree growth.

It is evident, therefore, that throughout the entire region, there was a well marked relationship between the type of soil, considered with regard to its water-holding power and drainage, and the plant association covering it. The main distinction which was noticed in this portion of the state as compared with other parts which have been visited, was that here comparatively slight disturbances of the drainage produced permanent swamp conditions, and this tendency increased, apparently, the farther north the investigation was carried until the valley of every rill was filled by a swamp.

On the other hand, except on rock hills, where sometimes 2 to 3 feet of humus had accumulated, there was usually only a slight development of humus upon the tops and sides of even the clay ridges, where the forest cover was most dense, although these gave evidence that they must have been covered by vegetation from almost immediately after the retreat of the glacial ice, in that there were practically no indications of rain erosion, even upon very steep slopes.

Types of Forest.

In order to more clearly present the general relationship between the swamps and the surrounding vegetation, an attempt has been made to classify the whole flora into a series of easily recognizable and fairly constant and characteristic types.

Summing up, there seems to occur in all these types of habitats, five fairly distinct and well-marked forest types, which may be characterized as follows, in the order of the extent of areas covered:

(1.) *The Broad-leaved, Hardwood or Deciduous Forest*.—This was the type which covered the better class of well-drained uplands, including the rock hills in undisturbed regions, and was the important forest of much of the region visited. The dominant species of trees in this type were Hard Maple, Elm, Basswood, Beech, in the south, and Yellow and Black Birch in the north, with more or less mixture of conifers, especially Hemlock, which sometimes is present to a considerable extent, and Balsam, White Spruce and Arbor Vitae, usually, when present, evidently recent comers, growing up in the shade of the hardwoods. In some cases White Pine was a constituent of this type, occurring as scattered individuals or small groves in the more sandy places or near the borders of swamps. In other areas all conifers were absent for long distances from the higher lands where the hardwoods reached their best development.

(2.) *The Coniferous Swamp Forest*.—This covered all of the un-drained or poorly drained flat lands, including the peat bogs. The more mature swamps had what has been called by the writer the Cedar-Tamarack-Spruce Association, in which frequently the Arbor Vitae or Cedar, was the dominant species, with a larger or smaller mixture of Black Spruce and Tamarack. The Tamarack, however, was very often abundant or dominant, and the Black Spruce sometimes covered considerable tracts with very few individuals of the other species present. In numerous cases the Cedar was wanting from the association where the other two species were present in about equal numbers. In this type also occurred at times the White Pine, the Jack Pine, and sometimes a few scattering Norway Pines and upon the borders, Balsam and White Spruce; Black Ash, White Elm, Balsam, Poplar, Red Maple and a few other species of swamp trees also were present in numbers sometimes sufficient to give a mixed character to the type, but this was rather unusual.

(3.) *The Hemlock-White Spruce-Balsam Type*.—This is also a coniferous type, and was found on well-drained flat lands and upon gentle slopes on the sides of the valleys. It had as fairly constant constituents, the White Birch, Yellow Birch and, in many cases, Arbor Vitae; in fact, most of the species of other types of associations occurred in it at times, but the species given were so frequently found together that an easily recognizable type can be maintained, which, in general, grows in situations intermediate in characters between

the Hardwood and the Swamp sites. Hemlock was the dominant species of the association and more frequently formed dense pure stands than either of the other species, which, rather rarely, were found in groves.

(4.) *The White Pine Type*.—Much more variable than any of the others was the type of forest in which the White Pine was the dominant species, from the great variety of conditions in which that noble tree will grow and thrive. Unfortunately the greater part of the White Pine in the regions traversed had been cut, but a few remnants remained, and the large areas of stump lands showed that at one time the type had been an important one. In this type are included all the mixtures in which the White Pine was the leading species in point of numbers, so that the range is from the two-storied White Pine and hardwood forest in which the old pines rise above the lower growing species, through the pure stand of White Pine, to the mixture of the three species of pines in which the White Pine was the important species. numerically. This would include all soil types, from gravelly loam with considerable clay in it, to poor but rather moist sands. This type apparently did not cover great connected areas as did the Hardwood type, but was confined to relatively small and disconnected areas of gravelly deposits of various geological history, and to partially covered rock outcrops.

(5.) *The Norway and Jack Pine Forest*.—Of more restricted distribution still was this interesting type, which seems to have been confined to tracts of dry, deep, thoroughly drained sand, whether in the form of ridges or plains, and the borders of tracts of this type of forest were often very sharply defined. Glacial sand or gravel plains, deltas, and sand dunes were the common habitats of the type, which is made up of rather open stands of the two species of pines which characterize it, mixed with some broad-leaved species, such as Poplars, Scarlet Oak and Red Maple, which grow with the pines in the most barren places. The type also occurs on sand ridges, a foot or so above the water level in many swamp areas, and sometimes invades the swamps themselves. The accumulation of humus under this type amounts to very little, in many eases to nothing apparently, although no evidences of fire could be discerned even by careful inspection. The Jack Pine, in young dense stands, was sometimes found growing in dryer parts of peat deposits.

The Drumlin Region Peat Deposits; Valley Bogs, Their Characteristics: Important Plant Associations of this Type.

The examination of deposits of peat began in the vicinity of Menominee, where, a short distance to the north of the city, there are numerous and practically unmodified Cedar, Spruce and Tamarack swamps which have an abundance of peat in them, and which afford interesting examples of the partial filling of shallow valleys by the growth and decay of vegetation.

The valleys in this locality are, in part, formed behind the ridges which mark the beach lines of higher levels of Lake Michigan and its predecessors, and in part lie in the grooves between the drumlins and the drumlin-like hills which are found in considerable numbers for many miles to the north of the mouth of the Menominee river.

Plate XIX. Mature Conifer bog, near Mansfield, rejuvenated to wet-sedge stage by severe fire, and now occupied by dense growth of Cat-tail. The surface was lowered at least two feet by the burning as shown by the upturned roots of the trees, from around which the peat was completely burned away. Uninjured swamp in the background.

These valleys are relatively broad and very shallow, with generally sandy bottoms, which may have a thin covering of fine clay, or, in a number of cases, what appears to be a grayish marl. Sometimes small streams run through these valleys, but frequently they have no running water in them, draining slowly towards the streams, the passage of the water being much retarded by the peat accumulations. The thin layer of clay or marl, which is found at the bottom of these beds of peat, seems to indicate that, in the beginning the valleys were occupied by very slow moving streams or shallow ponds, because such conditions favor the deposition of the fine mud or the growth of the aquatic plants which deposit the calcareous material which forms the marl. In no place visited in this vicinity were there any indications of the early stages of the process of filling these valleys and the order in which the plants forming the peat have invaded them, except that mentioned above, i. e., the marl. If, in the earliest stages, the valleys contained shallow ponds, it is highly probable that the first stages of the filling were done by aquatic plants, and that these were succeeded by the marsh plants.

The depth of the peat in these deposits is not great, many of them being but 2 or 3 feet deep, and they rarely exceed 8 feet, but the quality of the peat in them was better than that in the deeper deposits which were examined later, and after the surface layers, containing stumps, fallen logs and the roots of growing trees were passed through, much of it seemed sufficiently compact and well decomposed for economic uses. The color varied from light to dark brown, or, rather rarely, to black, and the amount of water was not excessive. There were

in the aggregate, large areas of this kind of peat bog within a few miles of Menominee.

The plants growing upon the surface of these deposits where they had not been cut or burned over, were usually a mixture of the following tree species: Tamarack, Black Spruce and White Cedar or Arbor Vitae. These were dominant or leading species, but with them were frequently small numbers of Balsam Fir, Black Ash, Balsam Poplar, Yellow Birch, White Birch, Bed or Soft Maple and Mountain Maple. The accompanying species were only present in a part of the swamps, and in these were usually found around the borders, or in partial clearings. In the best examples of this plant association seen in the region under discussion, that is, in which the trees were fully mature or past maturity, the marketable Cedar had been cut out, leaving the Tamarack and Spruce in numerical excess, and in rather open growth, while beneath these was usually a rather dense growth of low shrubs, chiefly those belonging to the Heath family.

Of these, the Cassandra was usually the dominant species and with this were present, in greater or less numbers, other species of the same family, of which Andromeda, the Pale Laurel, the Labrador Tea, and one of the low bush Blueberries, were the most frequent and noticeable. The Andromeda is especially conspicuous from its pale, bluish-green, narrow leaves, which are nearly white when young, and the Labrador Tea from the yellowish green color of the upper surface of its leaves and their dense woolly covering below. With these Heaths it was usual to find the Dwarf Birch, and not infrequently the Swamp Honeysuckle, which, in places, became the most abundant shrub. In spots where conditions were favorable, and especially where fire had destroyed the older vegetation, the Common or Speckled Alder was frequently the most important-species present, and even in apparently undisturbed places in the peat swamps, it was sometimes seen in greater or less abundance, although it was not so common in this type of habitat, as along streams. The herbaceous vegetation of these tree and shrub covered swamps in this particular area was made up largely of sedges belonging to the genera *Carex* and *Eriophorum*. Other types of herbs were present in the association, but were not large or constant constituents of it, and *Sphagnum*, the peat moss, was more often absent than present in the places visited, in fact, is noted as rather rarely occurring.

In places where fire has swept lightly over these swamps, simply destroying the surface vegetation, there frequently springs up a dense growth of young Tamaracks, which seem to be more hardy and more able to endure the conditions presented by this type of habitat than either of the other species of conifers, which, in other conditions, associate with them.

Here, as in the other regions visited, many instances of the effects of severe fires in changing the entire character of the vegetation growing upon the surface of peat deposits were noted. If the fire burned the peat so severely that the surface was lowered to such an extent that it was below, or very near, the subsequent ground water level, this area became covered by a growth of Cat-tail more frequently than by any other species, and as evidence that it was fire which had brought about the change, among the flags could usually be seen the dead and charred stumps of the trees which had formerly occupied the ground. Not uncommonly the edge of the fire scar would be abrupt, and this border would be marked by a fringe of tall old trees, and the accompanying shrubs which characterize the mature swamps.

One of the best of many examples of this form of accidental lowering of the surface of a peat deposit, was seen on the road from the Mansfield Mine to Crystal Falls, in an extensive valley swamp, a part of which is shown in Plate XIX.

In a relatively small area of sandy plain which lies in the big bend of the Menominee river, about 20 miles north of Menominee, there were numbers of shallow deposits of peat, from 1 to 3 feet deep, upon which were growing old Tamarack and Spruce trees in stands as dense as these trees usually form, a fact which is indicative of the unreliability of the indications of the surface vegetation as to the depth of the peat upon which it may be growing. In this area, in Tp. 35 N., R. 28 W., the following species of plants were noted growing under a forest of large and tall old Tamarack in a shallow depression in the plain:

Young White Cedar, Young Black Spruce, Young White Pine, Young Balsam Fir, Common Alder, Dwarf Alder or Buckthorn, Red-osier Dogwood, Swamp Honeysuckle, Dwarf Raspberry, Bunch Berry, Twin-flower, Swamp White Violet, Bristle-stalked Sedge, Little Prickly Sedge, Porcupine Sedge and Marsh Shield-fern.

In this locality there was very little Sphagnum. Another swamp of the same type, so far as tree growth is concerned, had the following species, not noted in the list given above, so abundant that they constituted practically the whole of the ground cover:

Cassandra (very abundant), Labrador Tea (growing on the elevations formed by the roots of the trees), Dwarf Birch, Hoary Willow (scattered among the other shrubs), Choke-berry (on the higher stools formed by the tree roots, etc.), River-bank Sedge (in the wettest places between clumps of shrubs), and Tussock Sedge.

Most of the herbs mentioned in the lists above, were present as minor constituents of the association, growing on the more exposed elevations above the water.

Partially Filled Lakes of This Area: Ways in Which They are Filled.

Hayward Lake

A few lakes were found in this area and of these, Hayward Lake, occupying parts of sections 2, 3, 10 and 11, T. 34 N., R. 26 W., situated .about five miles east of Ingalls station on the Chicago and Northwestern R. R., was the largest and first visited. This lake occupies a shallow depression near the border of the glaciated region and is surrounded by low drumlin-like elevations. There are several small islands in the lake and it seemed quite shallow from the north shore, which was the one visited. A large part of the shore was swampy, only two or three limited areas being high enough to support a dry ground flora to the edge of the water. The major portion of this swampy shore was covered to the water's edge by shrubs, of which the Dwarf Birch and Swamp Honeysuckle, several species of Willow, of which the Hoary Willow was the most conspicuous, and a constant admixture of Sweet Gale, which became nearly pure in a zone of varying width at the lakeward margin, where it was growing vigorously in water from a foot to 16 inches deep. The zone of shrubs had a width of from 40 or 50 feet, up to several hundred feet, in the part of the shore visited and was practically afloat with water several inches deep, only the elevations about the bases of the bushes being above water at that time, early in July. The margin was quite unstable in places, scarcely firm enough to bear the weight of a man, and settling perceptibly as it was stepped on. In the water beyond this quaking margin, were scattered plants of the Yellow Pond Lily, the White Pond Lily, and the Pickerel Weed, together with patches of Lake Bulrush, in somewhat deeper water. In some places the latter plant with the Cat-tail, formed a more or less extensive border outside the shrubs; several of the islands mentioned above were covered by the same plants and upon one of them a small tract of Tall Reed Grass was established, while still others bore shrubs and trees. The peat, in the places where the depth was tested along the margin of the lake, was from 8 to 9 feet deep, and was soft and contained much water. Below this were 6 inches of fine reddish clay, then hard bottom.

In a small indentation in the shrubby margin on this shore, the often-mentioned Slender Sedge and the Cat-tail had built a floating mat a couple of rods or more in width, upon which the Sweet Gale and some few small patches of Cassandra had established themselves, together with the Marsh Shield-fern, Reed Grass, the Swamp Persicaria, the Marsh Cinquefoil, the Myrtle-leaved Willow, and three species of sedge, the Water Sedge, the Bristly Sedge and Lesser-Panicled Sedge; the Water Persicaria and the Marsh Cinquefoil were more abundant back near the shoreward margin of the sedge mat, and of the shrubs, the Sweet Gale seemed to be making the most vigorous growth. There was 6 feet of soft peat below this mat and 6 inches of sandy marl before hard bottom was struck.

Shoreward of the shrub zone, extending around nearly the entire lake, was a zone, of varying width, of pure Tamarack, under the shade of which were relatively few other plants, which were not listed. The water here was not so deep as in the shrub zone, in fact did not stand above the surface, although the ground was saturated with water an inch or two below the general surface, the roots of the trees alone furnishing a firm footing. Farther shoreward, where the ground became firmer and dryer, the Arbor Vitae and Black Spruce were dominant trees; in wetter places, the Black Ash and White Elm occupied considerable areas. Under these two species, the water was sometimes knee-deep in the depressions between the trees. In a well-marked zone, between the Cedar-Spruce zone and the high ground vegetation, at the foot of the slope, was a mixture of White and Yellow Birch and Balsam Fir, the first named species attaining a diameter of nearly two feet and being the dominant tree species. The high ground forest, covering a low ridge of clayey till lying to the north of the lake, was chiefly a mixture of Beech, Hard Maple, Basswood and White Elm, the trees all of large size, and forming a dense shade, under which but few species of shade plants were growing.

Later it was reported that there were extensive cranberry marshes near the lake, but no indication of these appeared in the area examined, as the shrub and Tamarack zones were very dense as far as could be seen, and as noted above, extended practically all around the margin. The indications were in favor of the hypothesis, that at the time it was visited, the water of this lake was at least a foot higher than its normal level, as it seems hardly probable that some of the species of shrubs then growing in the water, would have been able to establish themselves where the water was so deep as in the places where they were found, and it is likely that the heavy rains, known to have prevailed a short time before, had recently raised the water level. Enquiries in the neighborhood regarding this point were fruitless, as the people living in this vicinity, said they rarely went to the lake, and knew nothing of the conditions existing at that time.

Apparently, filling in this basin is proceeding very slowly, and the greater part of it is being done by water plants, which are rather sparsely distributed along its shores in the shallow water, the absence of any extensive areas of sedge and the replacement of these by shrubby growth, pointing to relatively slow encroachment upon the open water by the plants, since the shrubs noted here, do not spread rapidly in the ways in which do the sedges.

The second lake or pond examined was a small one, of about 40 acres in area, in Sec. 3, T. 35 N., R. 28 W., in the sand plain mentioned above. This lake differed from Hayward lake in being surrounded by a pure sedge marsh on all sides except on the southwest, where there was a growth of Tamarack and shrubs shoreward of the sedge border next to the water. The species of sedge

which occurs here was, so far as seen, entirely the Slender Sedge, and it occupied practically all of the margin of the lake basin from the sandy region above the water level to a distance of from one to two hundred feet out, where the water was more than two feet in depth.

Plate XX. The sedge marsh on margin of a sand plain lake, shows besides the marsh: (1) Scattered Pond Lily leaves on the surface of the water; (2) Lake Bulrush in small quantity in the shallow water; (3) Standing stubs of burned White Pines; (4) Scattering young trees of the same species (on the left); (5) Young Pines and Poplars (on the right.)

At this distance from shore, the plants were growing in a soft oozy deposit of partly decomposed remains of water plants and growing algae, among which a species of Chara was easily recognizable by its whorled branches and peculiar odor. In this ooze the sedge was so lightly attached by its roots as to be practically floating, and it could be easily pulled away and turned over. The ooze was only a foot or two in depth below the edge of the growing sedge, and rested upon a sandy bottom in the places where it was tested. Growing in the water, beyond the edge of the sedge growth, where the depth was from two and one-half to five feet, was more or less of the Lake Bulrush, distributed in patches, usually of small extent. In the same zone and often associated with the Bulrush, were the White and Yellow Pond Lilies, and, more abundant than either here, the Water Shield, a small flowered member of the same family, together with the Floating Pondweed, and the Common Bladderwort, these, together, forming a rather sparse and broken zone, as far as the shore was examined.

Along the shoreward margin of the sedge zone, were logs which had fallen into the marsh from the shore, or had drifted thither during stages-of high water and upon these were colonies of Marsh Shield-fern, and Cassandra. These plants were also found in small patches growing among the sedge plants near the dryer edge of the marsh, and there were also specimens of the Myrtle-leaved Willow, other species of Willow and of the Marsh Cinquefoil. Above the level of the water there was a narrow zone of Blue-Joint Grass, which ran directly into the ordinary shrubby flora of the burned-over pine barren. This was not listed for this particular locality, but was made up principally of young growth of Poplars, both the common Aspen and the Large Toothed Aspen and the Wild Red or Pin Cherry, with a dense covering of Sweet Fern, the Bush Honeysuckle, the Common Brake, and a considerable number of low herbs and grasses. There was no time to visit the western shore of this lake, where a shrub and Tamarack zone were developed, but there seemed to be considerable extent of this type of swamp there, and it apparently extended along the outlet of the lake to a stream which flows a quarter of a mile west.

A portion of the margin of this lake is shown in Plate XX. This lake, as a whole, seems to represent a much earlier stage of the process of filling an extensive basin by vegetation, than does Hayward lake, and in every way, even to the species of the plants concerned, closely corresponds to the earlier stages of the process as worked out for the same type of basin in the Southern Peninsula, the only possible difference which could be noted being in the greater luxuriance of the growth of the water plants in the south as compared with that in this locality. Here the plants of the aquatic type were scattered and formed a very broken zone, but even this difference was probably no greater than would often be noticed in adjacent lakes in the south or even in neighboring parts of the same lake, in which, in one place, there will be a very luxuriant growth of this type of plants and in another a very sparse and poor one.

If a comparison of the plant associations of these two lakes is made, it becomes evident that the dominant association of Lake No. 2 corresponds very closely to the group of plants on the margin of the little inlet which was found at Hayward Lake and described above, but it is also clear that there is nothing at Lake No. 2 to represent the wide zones of bush and tree swamp which constitute the conspicuous features of the former in that part of the latter which has been described. The presence of some of the shrubby species which constitute the greater part of the association of the marginal zone of Hayward lake, upon logs and along the shoreward edge of the sedge marsh, is an indication that a distinct zone of shrubs will eventually be developed as the sedge marsh extends out over the lake, or at any time when the water level of the lake is lowered sufficiently to permit the shrubs to become established. It also seems probable that at Hayward Lake there has been a period of low water rather recently, during which the shrubs advanced to the margin of the sedge mat and so shaded it that the sedges were nearly exterminated, and have not yet had time to reestablish themselves since the water has risen, although conditions found farther north indicate that this is by no means certain.

Pond in Peat Bog at Nathan.

The third pond visited in this region is located at Nathan, a station on the Wisconsin and Michigan R. R. (Sec. 24, T. 37 N., R. 28 W.). This is a small pond of a few acres in area, a short distance west of the railway station, and surrounded by a peat bog of considerable extent and of

a very interesting type. (Plate XXI.) The bog represents a stage quite near the end of the process of filling a lake basin similar to that last described, a shallow depression in a nearly flat country, which, however, in this case, was not sandy but covered by bouldery clay.

Plate XXI. Lake margin at Nathan, Menominee County, shows: (1) The characteristic absence of aquatic vegetation in the northern peat bog lakes; (2) The narrow marginal zone of Cassandra in and over the water; (3) The Sedge-Sphagnum zone shoreward of this; (4) In the background, a dense growth of shrubs, stunted Black Spruce and taller Tamaracks.

The surface of the bog seems to slope gently from the border to the margin to the lake, and actually does, to a slight degree, as was shown by the standing water in a ditch cut from the road which runs west from Nathan to the lake, but the effect is probably heightened by the fact that the Sphagnum, which covers the surface, is much more luxuriant in its growth some distance back from the edge of the water, than it is near it.

Vegetation of the aquatic type, is practically wanting in the lake, the only plants noted being a small amount of an aquatic moss, *Fontinalis* sp., and small patches, near the shore, of the thread-like leaves of Water Club-rush, while upon small areas of bare peat, just above the water surface, were, here and there, stunted plants of the Yellow Pond Lily and of a Pondweed, probably a form of the Floating Pondweed. The bottom of the pond was apparently entirely made up of dark-colored peat of rather coarse texture and very soft. Above the surface of the water the vegetation was abundant and at different parts of the shore was quite different in character and species. In general, on all sides of the lake, however, the marginal zone consisted of occasional stools of Tussock Sedge with more abundant plants of Creeping Sedge, and in much greater amount than either of these Cassandra and Andromeda sending out branches into the water, upon which as supports, the sedges and the Large Cranberry grew, and helped to form a mat upon which grew Sphagnum, and later, other species. Both species of sedge mentioned formed independent masses extending short distances from the shore. At a varying distance from the edge of the water, but never beyond the advancing shrubs, usually more than one foot and often several feet back, there was a dense growth of Sphagnum, forming a well marked zone from one to several yards in width. Growing with this and often confined to this zone exclusively, were:

Creeping Sedge, Mud Sedge, Sheathed Cotton-grass, White Beaked-rush, Large Cranberry, Small Cranberry, Buckbean,[1] Sundew,[2] Pitcher Plant,[3] Andromeda,[4] Cassandra,[4] and Pale Laurel.[4]

The surface of the Sphagnum in this zone varied but little from a foot above the surface of the water in the pond, and the moss itself was saturated with water. In some places the moss was less thickly crowded than in others and in some spots it was nearly absent, in which cases the surface was somewhat lower and wetter than where it was present, as would naturally be expected, and in such places the sedges were usually more thrifty than where the moss was more dense.

The shoreward margin of this zone was marked by a border of taller shrubs, of which Cassandra was the most conspicuous in point of numbers and size, and by large numbers of stunted Black Spruces from three to eight feet in height, together with a few small and slow growing individuals of Tamarack. The Spruces were also evidently making very slow growth, as shown by the short leaders and narrowness of the rings in stumps examined. They were also badly infested with the Small Mistletoe and many of the individuals showed the characteristic "Witches' brooms," which this parasite causes before the tree dies.

[1]More common at the landward edge of this zone nearly buried in the Sphagnum.

[2]Also growing upon the bare mud near edge of the water.

[3]The leaves of this plant were practically buried in the Sphagnum, only the openings showing in many cases.

[4]The plants of these shrubs here were all short, many of them apparently young and recently established.

Associated with the Cassandra and Spruce was the Labrador Tea which did not occur at all in the Sphagnum zone near the water and grew here in the higher places, on the hummocks and stools about old stumps. Andromeda on the other hand was not abundant in this zone and was only seen occasionally in the part of the area visited. Aside from these plants the following occurred: Pale Laurel was abundant and of large size. The Pitcher Plant was not common and the plants seen were in poor condition as though not in a favorable situation, the leaves were small and few and the plants had not bloomed this season. In spots where openings in the shrub growth had developed, the Cranberries were able to cover the ground, but as a usual thing they were not present in this zone, but the little Creeping Snowberry was frequently seen running over the surface of the Sphagnum. The Three-seeded Sedge, the Sheathed Cotton-grass, and the Three-leaved Solomen's Seal were the only herbaceous plants seen besides those mentioned, the last named being very common. In the places which seemed the dryest, there were also occasional patches of the Canada Blueberry.

A rod or two back from the lakeward edge of this zone the Sphagnum was often very pale in color and quite dry at the top, as though dead, and it was only in the depressions and under the shade of the thin-foliaged, sickly specimens of Black Spruce that it seemed to be growing, and was green and fresh. Areas of several square feet in extent were frequent that were covered by the Reindeer Lichen which formed a dense mat upon the surface of the dead Sphagnum, apparently showing a condition of great dryness, since the Reindeer Lichen grows in this latitude only in the dryest situations.

In a few places the Sphagnum had built up mounds by the aid of the growing Cassandra bushes to a height of nearly 2 feet above the lowest part of the moss-covered surface, or slightly more than 3 feet above the water level, but the general surface of this part of the bog was from 18 inches to 2 feet above the level of the water, and it seemed apparent from the general condition of the Sphagnum plants that there would be very little growth above that level, unless the level of the water should rise, or the evaporation from the surface be checked in some way.

The peat here was more than 10 feet deep in every place where it was tested, and from the surface, through the first 6 feet, it was of rather coarse texture, compact and of a marked and unusually deep reddish color, quite different from the dark brown of ordinary peat. Below this it was finer grained, lighter in color and very soft and wet, but coherent enough to be brought to the surface in the sampler.

In the marginal zone, wherever the Sphagnum grew, the bog was firm and strong enough to permit walking over it with safety, but it was easily shaken, and lakeward of the Sphagnum would sink when stepped upon. In the zone of shrubs and spruce, the surface could not be shaken for more than a short distance even by jumping upon it with considerable force, so compact was the substratum.

Plate XXII. Border of mature bog near Nathan, Menominee County, shows: (1) The abrupt transition from sedge-marsh with slight admixture of shrubs to coniferous swamp. The conifers at the left are Tamarack, Black Spruce, and some Arbor Vitæ; on the right is less dense growth of stunted Black Spruce and shrubs with Sphagnum below.

This bog, more than any other which had been seen by the writer up to that time, would lead the casual observer to the conclusion that the lake was being filled by the advance of the Sphagnum over the surface. It was however, easy to see that such was not actually the case, for in no place around the entire margin of the open water was the Sphagnum growing in the water, in advance of other plants, and in the greater part of the margin it was a foot or more back from it, as has been noted above. Sometimes, however, the moss would be growing nearly at the edge of the zone of the advancing plants and the fact that it was not growing in the water beyond the pioneers, the sedges and the shrubs, was only determined by careful inspection.

It is evident, upon comparing this with the other two lakes described, that this is quite different from either, in the stage of its development, and represents very late steps in the process of which they were early ones.

The nearness of this bog to the railroad, its heavy covering of Sphagnum, and the probable freedom of the peat from objectionable sedimentary matter, make this deposit worthy of further study, with the view to making some commercial use of it, for although it is not of so great superficial extent as some other tracts seem, the moss upon it is unusually good, and the depth of the peat is greater than common.

Completely Filled Lake or Basin Near Nathan.

Considering the bogs as a series, the best example of a deposit which seemed to represent the final stage of the complete closing of a lake by plants was found about 1½ miles east of Nathan, on sections 19 and 20,

and extending north and south in Tp. 37 N., R. 27 W. Here, the open water had disappeared entirely, but there was a wet marsh covered with sedges and small areas of Lake Bulrush, which occupied the wettest places, where the water was an inch or two above the surface. Growing with the Bulrush in the water were the Buckbean and the Flat-leaved Bladderwort, and, indicating the approach of the end of the wet cycle, were an abundance of the well established, though small, plants of Sweet Gale, and not a few individuals of the Dwarf Birch, Cassandra, and Andromeda, as well as the Pitcher Plant, growing among the Bulrush stems.

Under one of these wetter places the peat was found to have the following section:

	Feet.	Total depth in feet.
Turf	1	1
Rather soft, poorly decomposed peat	3	4
Sludgy or very watery peat	3	7
Dark colored marl	1	8
Light colored marl	1	9
Sand at bottom		

The marsh around these areas of Bulrush was slightly higher, having the water level about two inches below the surface, and was covered with sedges, of which the Slender Sedge, the Twig-rush, the Alpine Cotton-grass

and the Sheathed Cotton-grass, with occasional plants of the Lake Bulrush, were the most important species. There were also a large number of low plants of the shrubs mentioned as occurring among the Bulrushes and here again was found the Pitcher Plant, and small specimens of Tamarack.

The whole surface of this area, except the "islands" described below, could be easily shaken with a relatively slight effort. The "islands" were groups of trees of various sizes which had established themselves upon the open marsh, the principal tree thus appearing upon the upon the marsh being the Tamarack. One of these islands not far from a considerable area of nearly pure lake Bulrush was about 75 feet in length and half as broad. In this area were several Tamaracks, 20 to 30 feet tall, one Black Spruce and one Arbor Vitae, while forming a rather dense growth beneath and around the border of these, were the following shrubby and herbaceous species: In the shade of the trees, were the Labrador Tea, the Sweet Gale, here much larger and taller than in the marsh, the Buckthorn, the Swamp Honeysuckle, the Large Cranberry, the Pitcher Plant and some low sedges. The Andromeda was growing abundantly around the outer edge of the island, but not under the shade, and the Bulrush grew close up to the island, but not in the shade of the trees. The surface of the marsh was no higher where these islands occurred, but the peat seemed somewhat firmer and less easily shaken on them, and the water level was slightly lower, but still less than 6 inches below the surface. There was no Sphagnum on the island described, nor on others, and none over a greater part of the sedge marsh, although near the shoreward margin it was seen in small patches either among the sedges, or more often, about clusters of shrubs.

Around this open marsh, on the west side, was a mature tree-covered swamp, Arbor Vitae, Black Spruce and Tamarack with an occasional White Pine, making the growth. The Tamaracks were the tallest, and, presumably the oldest trees in this association, overtopping the other species and appearing of greater age. The ground was covered by Sphagnum and a growth of shrubs, of which the Labrador Tea was the most abundant species, having some Cassandra and the Small Cranberry mixed with it in the more open places. The herbs noted here were the Twin-flower, trailing over the Sphagnum, the Swamp Valerian, the Sweet White Violet and the Kidney-leaved Violet, the Bog Wintergreen, the-Three-leaved Solomon's Seal, and the Soft-leaved Sedge. The peat here-was 9 feet deep, in places slightly more, firm and structureless below T feet. The water level was about 1 foot below the average surface. Quite different was the plant association of the border upon the eastern side of the marsh, where the Black Spruce in a stunted form, made up a large part of the tree growth. Here the surface of the bordering zone rose abruptly in many places, nearly or quite 18 inches, as though a wall had been built along it. This wall was of Sphagnum, and marked the edge of a dense growth of the shrubs, Sweet Gale, Cassandra, Andromeda, Dwarf Birch, and Labrador Tea, and occasional plants of the Hoary Willow. The Spruce trees were small, stunted, and were scattered thickly among the shrubs, with a few small Tamaracks and Arbor Vitae, while trailing over the surface of the Sphagnum, or growing in it, were the Creeping Snowberry, the Small Cranberry, and Three-leaved Solomon's Seal. Shoreward from the margin of this Sphagnum and Spruce growth the trees were larger and more numerous than near it, but all had a generally stunted appearance. (Plate XXII.)

Beyond the general border of the Sphagnum on this side of the open marsh, there were many plants of Cassandra, Andromeda, Sweet Gale and Dwarf Birch growing in the marsh, usually in small dense stools or clumps, and, about some of these clumps of shrubs, as centers of growth, but only occasionally, the Sphagnum would be found established, building up a mound a foot or more above the general surface, and apparently forming an advance colony from the compact shrub-Sphagnum-Spruce association. Upon such colonies of Sphagnum growing around shrubs, the Labrador Tea would sometimes occur, but it was not noted in the sedge marsh except in these elevated spots. These conditions, as described, seem to point to the advance of shrubs and trees and Sphagnum to a rather sharply drawn line which has been maintained for a considerable period, during which existing conditions were constant, and only recently, apparently for only a few years, has there been a change. It seems probable, in the light of what was observed elsewhere, that the sharp border of the marsh with its wall of shrubs and Sphagnum, is the former shore of the pond, which was later covered with sedges and rushes until the present marsh was formed, and that now the surface of this is being covered by trees and shrubs, which under the present stage of rather high water are making slow progress. The absence of the remains of trees and shrubs, and the structure of the turf where this was examined, seem to confirm the opinion that this area had not been before occupied by woody plants, at least not at the level of the present surface.

To the north of the area just described, at a distance of about 200 yards, the tree growth bordering the open marsh was found to be nearly pure Tamarack, under which there was very little Sphagnum, but an abundance of Lesser-panicled Sedge, Small Cranberry, Pitcher Plant, Buckbean and Dwarf Birch, which were the principal members of the association growing beneath the Tamaracks, with which were occasional plants of broad-leaved forms of Andromeda, and Labrador Tea, growing in the shade, and of the Alpine Cotton-grass. Here also were noted the Marsh Arrow-grass, Swamp Saxifrage, Marsh Shield Fern, Sartwell’s Sedge, Tall Cotton-grass, Showy Ladies' Slipper, Arethusa and Calopogon. The moss most common with this association was a species of Hypnum, and Sphagnum was not noted.

This Tamarack-Sedge association gradually changed, as the distance from the open marsh increased, to a Spruce-Tamarack-Sphagnum association, and this again near the western margin of the swamp was found to contain a large percent of Arbor Vitae. It would seem probable that the Tamarack covered portion of the marsh border is practically of the same age as the shrub-Sphagnum portion, but in the former, the Tamarack seeded in uniformly and thickly and grew so dense that the shrubs and Sphagnum were unable to establish themselves and have only appeared in the Tamarack association after the trees have begun to thin out, owing to excessive competition of the individuals with each other.

A detailed account of this very interesting bog has been given to show how varied may be the plant associations forming the covering of adjacent areas of the same bog, where there is so slight a change in the level of the surface and the ground water, that only the careful use of a spirit level would enable one to measure it in passing from one association to another, except where Sphagnum has become an important member of the association, and to explain all the peculiarities noted, would require an extended series of observations.

Algal Lake: Of a unique type was a rather extensive bog surrounding a small lake near Merryman's Lake on section 33, T. 38 N., R. 28 W., and section 4, T. 37 N., R. 28 W., and lying in the same basin with it. This lake was in a depression surrounded by low drumlin-like hills covered, in the main, by a hardwood forest, chiefly Beech and Maple, with some admixture of Basswood, Birch, Elm and Hemlock. The present lake is roughly elliptical in form and is only a few acres in extent, but is surrounded by a wooded swamp which is approximately a mile and a half long and which connects with the swampy margin of Merryman's Lake to the northwest. The sketch map, figure 9, shows the approximate shape of the lake and of the swamp surrounding it.

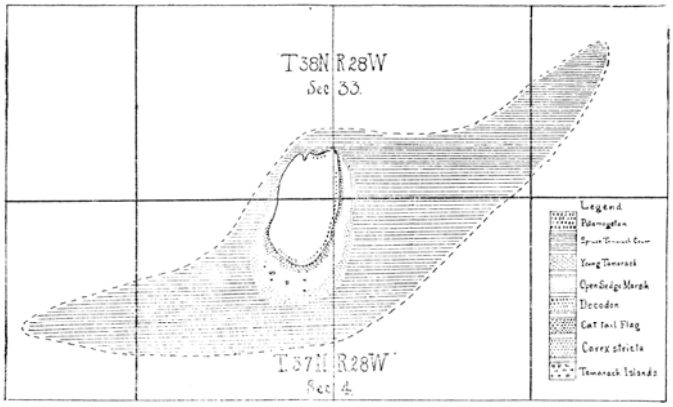

Figure 9. Sketch map of Algal lake, Menominee county.

After traversing the Tamarack-Spruce-Cedar swamp for some distance, the northern end of the lake, at which the tree association reaches nearly to the open water, was reached and a most striking fact relating to the marginal zone was at once apparent; it was made up nearly exclusively of the curious Swamp Loosestrife, which, up to this time, had never been observed in the Northern Peninsula, and indeed not far north of the central part of the Southern Peninsula. This plant is worthy of more than mere mention, since it is especially adapted to the lake margin habitat, and also because some of its adaptations enable it to make an advance outward from the shore each year when conditions are favorable, from the position it has been occupying and thus build a mat which will eventually cover the entire surface of the water. The plant is a perennial, forming clusters, or stools, of stems which are herbaceous, and die down each year, above the water, and have curiously thickened woody bases, which live through the winter, below it. The thickening is due in part to an enormous development of spongy, white, or pinkish tissue in the bark, which is supposed to aid the plant to increase the aeration of the submerged parts, since it forms only on parts of the plant below the surface of the water. This tissue is called aerenchyma, and is made up of a multitude of thin-walled cells. The thickening of this part of the stem is also due to actual increase in the diameter of the stem below the water and to a considerable development of hard, woody tissue, so that the real diameter of the stem below the water may be several times that of the herbaceous, aerial parts. The method of propagation of the plant is also of exceptional interest, for it not only bears and matures large quantities of seeds, but like many other plants growing in and about the water, it has developed a special vegetative method of establishing itself in new places. As they mature, the stems reach out in all directions from the top of the stools and after ascending obliquely to a height of 3 or 4 feet, curve at the tips and turn downward towards the water. Some of these continue to grow downward until they touch the water and reach below it a short distance, after which there is a development of the spongy tissue in the bark, and of wood in the submerged parts, and also of roots, which form in considerable numbers, and may eventually reach the bottom if it is near enough to the surface. From this submerged and rooted tip, buds arise and a new plant develops from these the next season if not before. In the fall the herbaceous or aerial part of the stem is killed by freezing, but the woody part remains alive, moored to the parent stool by the dead stem. This holds the tip with its roots and buds in an erect position, as well as prevents it from being washed away before it has become fairly rooted, and thus a new plant is not only established, but is held in place for a year or more, at a distance of from 2 to 3 feet, or even more, from the shore, advancing the shore line in this way with considerable precision and symmetry. As the plants send out their branches in all directions, some of them do not reach the water but come to the ground shoreward of the stool. These branches may run along the ground for several feet, as many as 6 or more, without becoming woody or forming any roots; such stems perish at the end of the season, so the greatest number of new plants are constantly established on the open water side of the old ones. As soon as the plants set off from the margin of the lake have become fixed in place and begin to increase in size, the water-loving

mosses, the algae, the Marsh Shield Fern, and a number of seed plants begin to grow about the roots, and on the stools, and soon reach across to and from the older plants and bind the whole together, at first by a loosely aggregated tissue of stems, but later by a compact turf. In the locality here described, the* compacting of the first structure is due to the rapid occupation of this by the shrubs, Cassandra and Andromeda, and by the sedges which soon, or even immediately, are followed by Sphagnum. After the sedges appear upon the stools of the Swamp Loosestrife, the latter plant is apparently unable to persist, for frequently the dead stems and remains of stools may be seen in the sedge marsh behind the zone of living stools at the water's edge.

In the lake under discussion, the Swamp Loosestrife was the chief marginal species around a greater part of the border of the open water, except in two limited areas where the Cat-tail disputed the ground with it, and for a short space on the east side, where the Tussock Sedge formed the margin. The latter plant will probably be displaced eventually by the Swamp Loosestrife, because the Sedge is unable to advance over the water rapidly, building high tussocks or stools by its growth and not a compact turf. The Swamp Loosestrife, therefore, once established among the stools of the sedge, would be able to reach out to the open water beyond them and thus become the marginal plant. At either end of the sedge area, the beginnings of this process of displacement could be observed.

The relatively high level above the water, of the surface of the stools made by the Swamp Loosestrife, affords a chance for a much greater variety of plants to grow than the wetter parts of the sedge mats, hence it is easy to see that after the surface is once covered by the pioneer species, its flora will be more diverse than that of the sedge mat, and will be built up more rapidly to a stage where it will support vigorous tree growth. In this particular instance there was a rather narrow zone just shoreward of the marginal zone in which the surface was higher than that still further shoreward, and upon this young Tamaracks and Sphagnum with several shrubs, such as Cassandra and Andromeda had established themselves, while in the wetter zone shoreward, as is pointed out below, these plants are wanting or are present in lesser amount. It is evident that the Swamp Loosestrife had not been present, at least in this part of the lake, for a very long time, since its remains could only be found in the area where the surface was higher, and this area was in many places only a few feet broad, and nowhere very extensive. The plant is then, one which materially hastens the upbuilding of the surface of a bog as well as rapidly extends it in a lateral direction over an area of shallow open water.

In the areas of Cat-tail near the north end of the lake were numbers of young Tamaracks, which here were growing about at water level, and reached nearly to the water's edge. In most other parts of the bog, young Tamaracks formed a rather dense zone, next to the older tree association, or occurred as mentioned, in small groups along the shore, or scattered in the sedge marsh.

In a small area of open marsh formed by clearing off the old timber, shoreward of the border of the Swamp Loosestrife, the following plants were noted: Sphagnum, Marsh Shield-fern, Cinnamon Fern, young Spruce, Tamarack, Arbor Vitae, Nerved Manna Grass, Blue-Joint Grass, Bristle-stalked Sedge, Three-seeded Sedge, Soft-leaved Sedge, Magellan Sedge, Hairy Wood-rush, Wild Lily-of-the-valley, Clintonia, Calopogon, Buckbean, Bunch-berry, Canada Blueberry, Wild Sarsaparilla, Goldthread, Marsh Marigold, Bound-leaved Sundew, Small Cranberry, Small Bishop's Cap, Small Goose-grass, Marsh White Violet, Dwarf Raspberry, Red Raspberry, Star-flower, Tufted Loosestrife, Twin-flower, growing on rotting logs, and Creeping Snowberry, growing on fallen logs and over the top of the Sphagnum mounds. The peat here was firm and moist at the surface, the water level about one foot below the surface, and the total depth of the peat 12 feet. The station was about the only place, where the Cedar-Spruce-Tamarack association had reached nearly to the margin of the open water.

Associated with the Cat-tail were quantities of the Marsh Shield-fern, growing slightly above the water level, on the débris of the dead flags, and of the Buckbean, in the water. Scattered plants of Swamp Saxifrage, Marsh Marigold, Marsh Cinquefoil and False Nettle, were frequent, and Swamp Loosestrife and Lesser-Panicled Sedge formed stools here and there in the more open places.

In a rather open part of the Cedar-Spruce-Tamarack zone, was a small pool of clear water, in which grew the Smaller Bladderwort, Water Starwort, Lesser Duckweed, one of the smallest of our flowering plants, Water Arum or Wild Calla Lily, and the Lesser Panicled Sedge. On the margin of this pool were numerous plants of False Nettle, Marsh Shield-fern, and Bristle-stalked Sedge. In the same zone in the dense shade of a clump of young White Cedars was much bare ground, with occasional scattered tufts of Sphagnum, and a few plants of Small Bishop's Cap, Marsh White Violet, Marsh Shield-fern, Wild Sarsaparilla, Goldthread, Clintonia, and Wild Lily-of-the-valley. The mosses were the most abundant type here. The Cinnamon Fern was abundant among the young Cedars, making a striking display with its large tufts of long fronds.

In going east along the north side of the lake, the Cedar-Spruce-Tamarack zone gradually leaves the water margin, while the zone of young Tamaracks becomes wider and the Cat-tail area narrower. Sphagnum follows rather closely the outer borders of the older growth, where it is abundant in the more open places; as far as the lakeward margin of this zone, beyond which it stops abruptly. In this region the Sphagnum is accompanied by Cassandra, Buckbean, and Pitcher Plant.

As the turn to the south is made, a narrow lane, or zone, of open, wet marsh begins, which runs along the east side of the lake to the south end, growing wider as it extends southward, until at the widest part it is several hundred feet wide. This is bounded for some distance on the lakeward side by young Tamaracks and some young Cedars, which here grow close to the margin of the water on the line of low hummocks built by the Swamp Loosestrife. As noted above, the Sphagnum is abundant in the margin of the old tree growth, and also on the hummocks-along the water's edge. For a short distance, a portion of this open marsh was covered by Sphagnum, apparently recently established upon it, since the moss was thin and short and the water only a few inches below the surface. Here Andromeda and the Small Cranberry were abundant, the former very short and small, as if lately established.

The Marsh Cinquefoil, a small leaved form of the Buckbean, Pitcher Plant, the Lesser-Panicled Sedge, Mud Sedge, Prickly Sedge, Slender Cotton-grass, Tall Cotton-grass, Scheuchzeria, and the Tall Green Orchis were the only species present, the whole forming a spongy turf. The same species, in about the same relations, as to abundance and water level, were quite generally present in parts of the open marsh where the Sphagnum was not present. The Marsh Shield-fern and Cassandra, conspicuous members of the society bordering the open marsh, were absent from it, and as the level of the surface of the marsh was from 1 to 2 feet lower than that of the Sphagnum-covered borders, it seems probable that the level of the water may be a controlling factor in the distribution of these plants here.

The open marsh continues along the east side of the lake, becoming wider on the south and southwest sides where the Slender Sedge becomes the most abundant plant, giving a different appearance to the surface, because of its uniformly greater height than the rest of the plants with which it is associated. Here at the south end, the zone of Swamp Loosestrife became 20 to 40 feet wide, and the sedge marsh more than 300 feet. The sedge marsh here has Sphagnum and the Small Cranberry over considerable areas, and islands of young Tamaracks and shrubs scattered over it. Where the Sphagnum is not present, the Pitcher Plant, Cat-tail, Buckbean and Marsh Cinquefoil are most abundant, and over much of the area where these plants were abundant, the water rose very nearly or quite to the surface of the marsh. The same type of marsh, though narrower, and nearly the same plants continued toward the north end of the lake on the west side.

Considering now the marginal zone, and the lake itself, the former was chiefly made up of the Swamp Loosestrife, as has been already pointed out. The stools of this plant were frequently so near together along the margin of the water, that they were separated only by a foot, more or less, of open water, and the tops were a foot or fourteen inches or even more above the water; from the top of these stools the growing stems rise, and the diameter of the stools may be more than a foot.

Upon these stools the Marsh Shield-fern is one of the first plants to appear after the mosses. Sphagnum, the Cranberries, Cassandra, and the Marsh Cinquefoil, and several species of Sedge were noted as growing upon the newer stools, while the older ones were completely covered by the advancing vegetation of the Cedar-Spruce-Tamarack zone, including young trees of a diameter of several inches. Some of the marginal stools were still isolated from the mat and were easily overturned. The mat, at the firm margin, was about two feet thick, and below this depth, the substratum was a soft light brown ooze, so filled with water that it was practically a fluid.

A study of the relationship of the zones described, led to the conclusion that the Cedar-Spruce-Tamarack zone, with its rather abrupt margin of Sphagnum and shrubs was older than the rest of the bog, and that after this had been developed, a sedge mat had slowly extended itself over the water. At a comparatively recent period, the Swamp Loosestrife had become established on the lake margin and the zone of young Tamaracks, shrubs and Sphagnum had been built up on the stools of this plant, which gave a surface sufficiently elevated above the water to enable these rapid turf formers to establish themselves at once rather than wait for the slow upbuilding of the deposit by the accumulation of the remains of sedges and other water-tolerant plants. The recent appearance of the Swamp Loosestrife is considered probable because of the narrowness of the marginal Tamarack zone.

The description of the lake itself has purposely been left until the last since it presents the most interesting phase of all. The water, seen from the shore, seemed about a foot deep, as far out as it was possible to see. There were no aquatic plants growing in it, except in a narrow zone, some 15 feet wide, close to the shore, which extended about half way around the lake. This zone was made up of plants of a single species of *Potamogeton*, a small, slender form growing only about a foot in length, and making very little show in the water. On sounding, to test the character of the bottom of the lake it was found that it was simply a soft, flocculent ooze, and in collecting samples of this, it was seen to be of a light brownish pink, or pinkish brown color, entirely structureless to the naked eye and hand lens, and of a salvy consistency very different from ordinary peat, even when thoroughly decomposed. A series of samples was taken from the shore of the lake back into the Cedar-Spruce-Tamarack zone, to see if the same type of material occurred beneath these older parts of the bog, as well as in the present lake. It was found that at the margin of the firm turf, the pinkish material was only two feet below the surface; at a distance of 30 feet from the lake it was about 4 feet from the surface; near the middle of the strip of open marsh, from 60 to 75 feet from the water's edge, it was 5 to 6 feet from the surface and just within the Cedar-Spruce-Tamarack zone it was nearly 8 feet down. (Fig. 10.) This station was estimated to be about 150 feet from the water's edge, where the surface of the bog was nearly two feet above the water level.

The change from one type to the other was abrupt, and the overlying material was of a dark color and had the usual coarse texture of the upper layers of a bog of the common type.

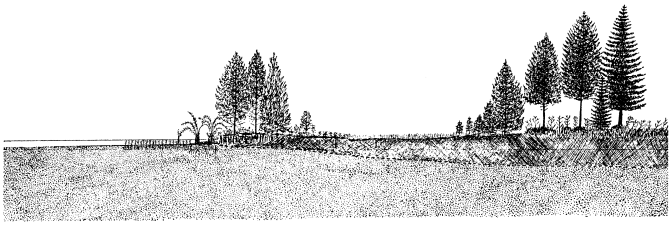

Figure 10. Ideal section showing the approximate relation (1) of the different types of peat, and (2) the plant societies from the water to the coniferous tree zones at Algal Lake.

The thickening of the coarse material back from the margin of the open water was apparently due (1) to settling of the surface layers, as the weight of the vegetation growing upon them increased, (2) to the upbuilding of the surface above the water level by Sphagnum and other plants, and possibly (3) also to an elevation of the level of the water itself, as the mass of vegetation and vegetable débris upon the surface grew broader and thicker and choked the outlets more and more. It is easy to conceive under such conditions, that the surface of the water would be raised while at the same time there would be a slow building up of the surface of the bog, because of the favorable conditions for the growth of important peat-forming plants, and for the preservation of their remains.

But two small samples of the peat of the lower layers of the deposit and from the lake were preserved for farther examination, but under the compound microscope several important facts were brought out, among which are the following: The material shows the same structure, or lack of it, in both samples; a large part of it seemed to be remnants of minute algae, apparently unicellular forms, with diatoms occasionally or sometimes freely mingled with these. There were no fragments of the tissues of higher plants present and only occasional short segments of the filamentous green algae, but in every slide examined, the most prominent recognizable structures were the peculiar three-celled pollen grains of the conifers, which seemed to have accumulated in vast numbers here. From the fact that there was no greater number of coniferous trees about this lake than many others, where the pollen grains have not been observed in the deposit, it seems evident that they are noticeable here because of the lack of coarser material to hide them and because of the relative small amount of the algal material laid down each year. The pollen grains from 12 feet below the surface, were well preserved and showed as characteristically as those from nearer the surface. Unfortunately, no specimen from the surface of the bottom of the lake was preserved, so that the chief species of algae present were not identified.

The bearing of this observation upon the question of the origin of structureless coals, such as Cannel coal, is worthy of passing mention, for it is apparent that peat of the type under consideration, under proper conditions, would change into a coal which would show little if any structure, no matter how carefully it was examined. The only organic remains which might be identified would be the pollen grains and the silicious shells of the diatoms, just as the spores of some of the Lycopods of the Carboniferous time have been reported as occurring in the European Cannel coal. The possibility suggests itself that, in the Carboniferous age, when all vegetation was of lower types than at present, and the plants now insignificant were then dominant, the simple algae were more abundant, and contributed largely by their activities to the deposits which have since been converted into coal.

Merryman's Lake.

This is a much larger body of water than the small one just described and lies near it. The shores are generally high and there is no extended swamp around it. The water is apparently shallow, for some distance from the shore, as scattering patches of Lake Bulrush extend over a large part of the lake. The margin generally has a narrow zone of the Tussock Sedge and the Slender Sedge. Toward the west end this zone widens, the Slender Sedge being here the most abundant species, forming a broad sedge mat, upon which, however, the Tamarack, Black Spruce, and White Cedar push out to within a short distance of the open water. These trees also form a generally very narrow zone shoreward of the sedge zone, except where fire or man has disturbed the original condition, in which case open ground, or Alder and Willows of various species, replace the conifer zone. In the edge of the sedge zone, on the lakeward border of the conifer zone, near the west end of the lake the following plants were noted in some abundance: The Marsh Shield-fern, abundant, especially on the hummocks about the bases of trees and on sedge tussocks, the Hoary Willow, very common in the marsh, the Marsh Cinquefoil, Calopogon, including a white flowered form, some Cat-tail among the sedges, Arrow-grass, occasional in the same situation; Sphagnum only around the trees, Hypnum more or less common in the wet parts of the marsh. On the hummocks in the marsh, with the Marsh Shield-fern, were the Dwarf Raspberry, the Three-leaved Solomon's Seal, the Cranberries, Hartwright's Persicaria, Creeping Snowberry, Goldthread, patches of Showy Ladies' Slipper, Twin Flower running over logs and stumps, Labrador Tea on hummocks about trees, the Common Horsetail, Bog Wintergreen, the Bristle-stalked and Slender Sedges, a rather common association in the advancing border of the conifer zone. The narrow zone of swamps about this lake, when its water was so shallow, and other conditions were apparently so favorable for swamp formation, is the remarkable thing about it and was not explainable from any facts observed in the limited time devoted to its examination.

Small Lakes Near Merryman's Lake.

In the same vicinity, a small pond was visited which had formerly had a thick growth of Tamarack and Spruce about it, but this had been burned off, and the swamp had grown up to a rather dense thicket of Aspen, common Alder and several species of Willow, with a narrow zone of Cat-tail, Bottle Sedge, and Sartwell's Sedge in shallow water lakeward, with the Lake Bulrush where the water was a foot or more deep. In still deeper water the Yellow Pond Lily formed a nearly complete zone from 20 to 50 feet wide around the entire pond. With the Pond Lilies were numerous specimens of Greater Bladderwort and a species of Water-milfoil, an association common in the Southern Peninsula, but not before seen in the Northern Peninsula.

In Figure 11 the water relations of these plant zones are indicated.

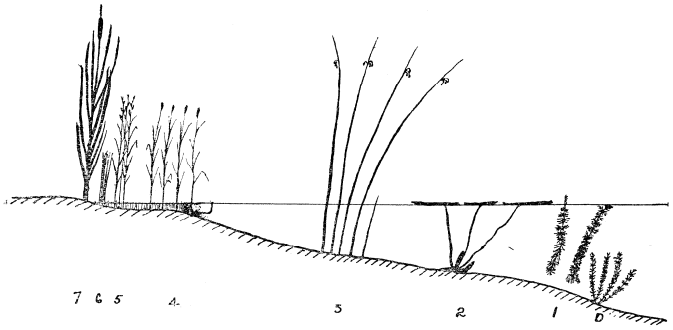

Figure 11. Diagram of plant zones in small lake near Merryman's lake.

0. Chara.
1. Floating Bladderwort.
2. Yellow Pond Lily.
3. Lake Bulrush.
4. Sartwell's Sedge.
5. Bottle Sedge.
6. Spike Rush.
7. Cat-tails.

In the sedge zone Hartwright's Persicaria, the Larger Blue Flag, Swamp Milkweed, the Marsh Cinquefoil, Joe-Pye Weed, Blue-Joint grass and the Marsh Shield-fern, were the most common plants, with the River-bank Sedge, Shining and Bebb's Willows, Marsh Skullcap, Marsh Bellflower, Nerved Manna-grass, Dark-green Bulrush, and the Swamp Thistle less common, and in the dryer spots the Red-osier Dogwood. This whole association, as will be seen upon comparing it with the others recorded from the vicinity, is remarkably different, closely resembling that found in the southern part of the state in peat bogs which have been partially drained. It is probable that the burning to which this swamp had been subjected made it possible for these plants to find a foot hold here. There was no Sphagnum present so far as observed.

In contrast with this was another swamp a short distance away, with a small lake, in it, but which had not been burned over. The swamp was covered with Tamarack and White Cedar, with a few Black Spruces scattered among these, and extending to within about a rod of open water. On the lakeward margin of the coniferous zone, was a narrow zone of Common Alder and various Willows, and then a broader zone of Slender Sedge, which was apparently encroaching slowly upon the lake, since it formed on its lakeward margin, long narrow projections into the open water, which here was quite shallow. In the little bays thus formed the Yellow Pond Lily was established.

Associated with the Slender Sedge upon the open marsh, were the Hoary Willow, scattered plants of the Cat-tail, the Marsh Cinquefoil, Marsh Shield-fern, Buckbean, and the Shrubby Cinquefoil. The latter plant was most abundant lakeward at the margin of the sedge zone, where, with the Swamp Honeysuckle, it formed in the more open places, a narrow, interrupted zone.

Sphagnum covered occasional spots in the conifer zone, but was nowhere abundant. In the same zone the following species were noted: Spurred Gentian, Twin-flower, Showy Ladies' Slipper, Creeping Snow-berry, Buckthorn, Silky Cornel, Low Raspberry, Star-flower, Bog Wintergreen, Common Alder, Yellow Sedge, Labrador Tea, Common Sundew, Small Cranberry, and the Tall Green Ochis. In this lake and swamp it was again apparent that the active plant in covering the open water was the Slender Sedge, aided by the Yellow Pond Lily, which was here able to grow with considerable luxuriance, and, without doubt, contributed considerably to the peat. Here, as elsewhere in this region, Sphagnum was not present upon the wetter parts of the advancing plant zone, nor in the water, but was confined to the older and dryer areas, mostly those in the coniferous zone.

Hermansville Bogs.

(1.) *A mature bog*. In an extensive Tamarack-Spruce-Cedar swamp about a mile east of Hermansville, on Sections 6 and 7, T. 38 N., R. 26 W., and running over into adjoining sections, the Black Spruce was more abundant than usual; the White Cedar large enough for commercial purposes had been cut, but there was some reproduction and young trees of the species were thrifty where seen. Ditches run along the sides of the road east from Hermansville, but they have not drained the swamp to any extent, the water in the ditches being 1% to 2 feet below the surface and in the swamp from 1 to l1/^ fe%t or 2 feet from tops of hummocks. The removal of the mature Cedar had allowed the light to come in more than usual in such mature swamps, with the result that the shrubs and the other low plant species were numerous and luxuriant in their growth. Sphagnum was also very abundant, forming a quite uniform layer, somewhat uneven at the surface and 1 to 2 feet thick. The shrubs noted here as more or less-frequent were the Dwarf Birch, Buckthorn, Swamp Honeysuckle, Hoary Willow, Red-osier Dogwood, Cassandra, Labrador Tea, Andromeda and Dwarf Raspberry; Wintergreen and Creeping Snowberry were found on the tops of the hummocks, the former on the dryest of these, upon which the Reindeer Lichen had established itself. The

Small Cranberry was also noted in spots on the Sphagnum, but was not so abundant as this species often is, in similar habitats.

Plate XXIII. Pine "Island," Lake Antoine, near Iron Mountain, showing Spruce, Tamarack, shrub and sedge bogs. Norway Pine on the island; Jack Pine and Common Brake in the foreground.

The herbaceous species here, were Slender Cotton-grass, Magellan's Sedge, Soft-leaved Sedge, Bristle-stalked Sedge, River-bank Sedge in depressions, Twin-flower, Gold-thread, Swamp Valerian, Marsh Shield-fern, Wild Lily-of-the-Valley, Three-leaved Solomon's Seal, Swamp Saxifrage, Swamp White Violet, Wild Calla, growing in moist Sphagnum, Bog Wintergreen, Small Bishop's Cap, Showy Ladies' Slipper, Manna-grass, usually in the wetter places, and the Bunchberry on top of the dryest hummocks, with Reindeer Lichen and Wintergreen. Along the road, and in larger openings, were numerous specimens of Common Alder, often forming dense clumps, but this species was not seen in the less disturbed parts of the swamp and seemed to be a clearing plant where it was present.

This section is represented by the diagram, Fig. 12, below.

The peat was tested near the middle of the swamp, where it was crossed by a road and was about 14 feet deep, the first 5 feet being rather coarse textured and full of roots, fallen logs, etc. Below this for 5 feet it was brown in color, of good texture and quite plastic, while the lower 4 feet were soft and light colored, suggesting the algal peat described above, in color and texture.

Apparently the upper 5 feet of peat had been deposited since the trees and shrubs had established themselves in the swamp while the lowest parts of the deposit seemed to have been formed under water, as the light color of the material precludes the idea of thorough decomposition, since that not only disintegrates the material but blackens it at the same time, often in proportion to the completeness of the decomposition. This deposit was in a poorly drained valley in the drumlin region, and represents the mature type of swamp for the region, except that the flora was rather richer than usual, because of the removal of the Cedar. There was no indication here or elsewhere in the region of the drumlins, so far as observed, of this type of swamp plant association passing into any other tree society, and it seems probable that it is a climax society for the habitat.

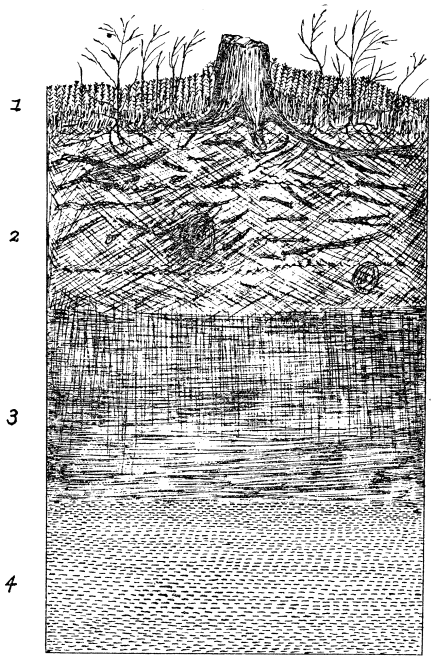

Figure 12. Section through a mature peat deposit near Hermansville, Menominee county.

1. Surface vegetation.
2. Layer containing roots and coarse vegetable débris.
3. Fully decomposed dark peat.
4. Light colored structureless peat.

(2.) *Cleared Bogs*: It was unusual to find any of these mature peat deposits which had been cleared with a view to cultivating them, but just west of Hermansville, in the depression between two large drumlins, was a small bog which had been ditched and stumped and cultivated for two or more seasons before the owners decided that the soil was not adapted to crop plants, and when visited, was reported not to have been plowed for several seasons, and so it had begun to revert to the wild state again. Some of the cultivated grasses and clovers had established themselves in the loose-textured dry peat, and were growing well; the native plants found persisting, or introduced since the land had been abandoned, were the Common Aspen, Labrador Tea, Cassandra, Canada Blueberry, Bristly Sarsaparilla, The Wild Red Cherry, and an occasional small Tamarack. The herbaceous plants besides the cultivated species mentioned, were the Common Brake, Sheathed Cotton-grass, Few-seeded Sedge (rare), Three Seeded Sedge, forming low stools, the Three-leaved Solomon's Seal, Sheep Sorrel, Great Willow-herb, while in many cases the ground was covered by a dense growth of the Hair-cap Moss, the same, or closely related, species that was found commonly on very dry, sandy soil, or in crevices and on ledges of exposed rocks. The loose texture of the partly decomposed plant remains making up the top layers of this bog, and the drought-resisting or xerophytic

character of most of the native plants growing upon it when visited, as well as the depth to the water table, more than 2 feet, in the ditches, point to insufficient or unavailable supply of moisture as an important factor in rendering the ground unfit for cultivation until farther decomposition has compacted the peat and lowered the surface.

Undoubtedly, also, the small amount of mineral food available for plants, as well as other considerations would need to be taken into account in working out all of the contributory causes of failure of crops on the area. At the time it was visited it gave every indication of becoming a brush swamp in a short time. It was reported to have been covered with Cedar before it was cleared.

Bogs Near Faunus.

Near the northern limit of the drumlin region, southeast of Foster City, along the line of the Chicago and Northwestern R. R. is a considerable district in which limestone ledges lie very near or at the surface. These exposures are flat, which makes the surface of the ground level and the drainage poor. These flat surfaces of limestone with thin soils were formerly often covered with Cedar-Tamarack-Spruce swamps, from which the valuable timber has been stripped. Following the lumbering, fires have destroyed some of the remaining trees, but many of the areas still show swamp conditions in the vigorous growth of young Tamarack and Cedar. It is a noteworthy fact regarding these swamps, that the peat upon them is generally very thin, coarse in texture and poorly decomposed, so that here, as elsewhere, the top of even the shallow deposit is often very dry.

It is an interesting fact, also, that in many places where there were well-developed swamps, the rock was so near the surface that telegraph and telephone poles were held in place by stones piled about the bottom, because holes could not be dug sufficiently deep to hold the poles in the shallow soil. Generally in such areas the peat was not more than 18 inches deep and frequently less than this, and was covered, in the burned-over tracts, with a dense growth of Alder, Willow and Poplar, or by young Tamarack, or less frequently, by young Cedar and Tamarack mixed. The flatness and impermeability of the rock surface seem to be the controlling factors in developing these swamps, since they tend to keep the ground water level high. The thin layer of till which may lie below the peat and above the rock surface is usually gravelly and serves to store some of the water which falls on the surface.

In T. 41 N., R. 26 W., between the water tank on the C. & N. W. R. R, and Faunus station, is a valley swamp bordering a small sluggish stream flowing into Ford river, which gave some exceptionally interesting opportunities for the study of the tolerance of water exhibited by bog plants. The valley was very shallow and the slopes slight, so that drainage was very poor over most of its bottom, which had been covered by a mature Cedar and Tamarack forest before it was disturbed, by lumbering and fire. In crossing the swamp, on sections 19, 20, 28 and 29, much of the material for grading up the road bed of the railroad had been dug from the right of way on either side of the grade, leaving shallow ponds and broad ditches in which the water stands to a depth of 18 inches or 2 feet below the surface of the peat on which most of the species of shrubs and perennial herbs of the mature Tamarack-Cedar-Spruce association were growing. These plants, since many of. them propagate by underground stems, have grown out into and over the ditches and ponds, until these have been nearly filled up in some places. In a few instances the growth covering the surface of the water was of mosses, chiefly species of *Fontinalis* and *Hypnum*, but in one instance *Sphagnum* seemed to be the form, although the plant was seen from a distance, and the observation is uncertain. A higher type of plants was represented in the Pond-weeds, which are true aquatics and may have been introduced into the ditches from the stream or from a distance by birds or other animals. The plant which was most effective in covering the open water, however, was the Marsh Cinquefoil, which sent out long branches from the sides of the ditches and ponds and often completely covered the surface for some distance. This species was never observed by the writer as the marginal plant over considerable areas along the shores of lakes, but here, around the artificial openings in the turf, it demonstrated its fitness to serve as the advancing plant in open water by forming dense mats, which soon serve as a basis for growth of a number of species of sedge, especially the Creeping Sedge, and for the Wild Calla and a species of *Hypnum* moss. The Marsh Cinquefoil is apparently killed by the encroachment of the Sedge, as, where this was present, the first plant was not as luxuriant as where there was no admixture of other species.

Next to the Marsh Cinquefoil, Andromeda was most frequent in its extensions into the water from the sides of the ditches, and long, rootless branches, 2 to 3 feet, or more, long, reached out into the water, often with only the tips of the terminal leaves above the surface. This plant did not form extensive mats, as the number of individuals along the sides of the ditches was not large in any one place, but the subaqueous shoots were normal and vigorous, and, in time, would serve as the basis for attachment of other species. Cassandra was also abundant, growing in the water in the same way as Andromeda and because of its more compact habit of growth, it was perhaps more frequently the center of development of small islands of other plants, which eventually became joined permanently to the bank of the ditch, and thus formed solid land. Other shrubs which extended out over and into the ditches and pools from the banks, forming more or less compact mats, were several species of Willows, the Dwarf Birch, Alder, and the Buckthorn.

Of herbaceous plants, the Creeping Sedge was found most frequently, forming extensions from the banks, both alone, and as an associate of other species, sending out

horizontal, cord-like, leafy stems sometimes 4 feet long, either in the water or over the surface of areas filled by floating moss. This sedge does not form a compact mat, as it forms roots rather infrequently along the prostrate stems, but it serves to bind other species together when its strong stems are overgrown by them.

The Wild Calla was doing similar work, extending its thick, freely rooting, prostrate stems, which bear numerous broad leaves and large flowers, in dense masses from 3 to 6 feet wide, out from shore on a substratum of moss, floating in the water. The plant thus forms a foundation for other species, and at one point the following species were growing with it: The Porcupine Sedge, forming small tufts, the Marsh Skullcap, the Great Water-dock, Blue Joint Grass, a Willow, the Small Bedstraw, and the Bulb-bearing Water Hemlock, a small part of a common open wet marsh society in which usually some species of Sedge is the dominant plant.

Other herbaceous plants which were noted as forming extensions from the shore in the pools were the Cat-tails, Hartwright's Persecaria, and, more rarely, the Buckbean. Growing in the water with the Pondweeds, were the Lesser Bladderwort, Pursh's Buttercup, and a very slender form of the Broad-leaved Arrowhead, while the Swamp Horsetail formed dense masses in some pools, rooting in the peat in a foot or more of water. It appears from the considerable variety of types of plants in this artificially formed habitat, in a locality where the number of species is rather restricted, that for a time, at least, those species which are present and establish themselves first are the ones which are able to occupy the space, but that later, other types come in, and wholly, or in part, dispossess the pioneers.

Plate XXIV. North side of small lake, near Bad Water Lake, showing: (1) Thin zone of Pond Lilies in shallow water; (2) Narrow zone of Sedges on a gently sloping shore, making a thick turf on sandy bottom; (3) Cassandra and other shrubs forming thick growth up to the higher ground; (4) Background of Norway Pine and White Pine. The area shown in Plate XXV is at the extreme left of the picture.

Peat in the Morainal Regions.

Bogs in Sand Plain Near Vulcan.

The first bog visited in the morainal region was in an extensive sand plain south of Vulcan in T. 39 N., R. 29 W., Sec. 15. The bog was a small one in a depression without outlet in the sloping sand plain and was originally surrounded by a forest of nearly pure Norway Pine, now represented by a remnant of a few acres in extent, on the south side of the depression. There was no open water upon the surface of the bog, but it was an excellent example of a type which is perhaps our nearest approach in Michigan, to the European "Hochmoor." In the middle of the bog was an irregularly elliptical tract in which Cassandra was the dominant plant, but with some dwarfed young Tamaracks, a single dead Norway Pine, and some dead Tamaracks of larger size, as well as Andromeda, Pale Laurel, Small Cranberry and the Slender Sedge. The surface here was built up by Sphagnum to about a foot above the water level, around the clumps of the Cassandra, and other shrubs, but this high level was not maintained uniformly, as there were numerous depressions reaching the water, where the Sphagnum had not yet grown as high, in which the Pitcher Plant, Buckbean, and Mud Sedge were common. Shoreward of this raised portion, was a broad zone of apparently pure Slender Sedge, but associated with it, on closer inspection, were found the Marsh Cinquefoil, the Myrtle-leaved Willow, and in the border next the elevated portion, and on the south side of it, Sphagnum growing in the water. On the north side, however, there was no Sphagnum with the Sedge. The water was from 1 to nearly 3 feet deep in this zone and the bottom easily shaken. Nearer the shore, the water was uniformly about 18 inches deep and in this part of the zone the Nerved Manna-grass, Tall Cotton-grass and Marsh Cinquefoil were generally present in abundance. This zone extended shoreward nearly to the water's edge, and merged into a well-defined but narrow zone of Blue-Joint Grass, and this, in turn, into another of Meadow-Sweet, about a foot above the water level, and above this, Alder formed a dense zone to about 3 feet above the water level, above which the Norway Pine association began abruptly and covered the slopes. The chief variation in this zonation was, at the east end, where the Cat-tail formed a partial zone shoreward of the Slender Sedge, and the replacement of the Norway Pine by pasture and cleared-land societies on the north and west sides of the valley. The very considerable depth of water in which most of these bog societies were growing, 2 feet, and more, in parts of the sedge zone, seems to indicate a recent rise of the water level, due to excessive rainfall, and it is probable that most of the zones were established in a time when the water was lower than at present, and, except the trees, have persisted during the rise, which would be very rapid in an enclosed basin of this type; the dead Tamaracks and the Norway Pine would indicate such a rise in the water, as trees are more often killed in this manner than the more

tolerant sedges, grasses and other herbs and shrubs. A fire sweeping across the swamp would also destroy the trees, and not, necessarily, the herbs and shrubs, but no marks of fire were observed.

Other Kettle Hole Bogs Near Vulcan: A group of small depressions a mile south of the one just described, form an interesting series. The depressions were four in number and situated in Sec. 22, T. 39 N., R. 29 W., near the border of a portion of the gravel plain mentioned above, which had been cleared and cultivated. The larger one of the series had a small pond in it, which was surrounded by a wide quaking bog covered largely by shrubs and sedges. The water in the pond was shallow and had the Yellow Pond Lily scattered over nearly the whole surface, while near the shore there was an interrupted zone of Creeping Spike-rush pushing out towards the center and a mat of Slender Sedge following it. Upon the sedge mat were scattered plants of Dulichium, Scheuchzeria, Buckbean, and Marsh Cinquefoil, and also islands of Cassandra at distances of from 20 to 50 feet from the edge of the open water. Upon this part of the sedge mat the water was about a foot deep, and in the water was an abundance of Hypnum moss, which, near the shoreward margin of the sedge mat, was more or less displaced by submerged Sphagnum. In this part of the mat also were found the Marsh St. John's-wort and the Bulb-bearing Water Hemlock.

Still nearer the shore, the surface rose a foot above the water level and the shrub-Sphagnum zone proper began, though the whole mat was still easily shaken. The plants of this association were Cassandra, Andromeda, Large and Small Cranberry, Tamarack, White and Norway Pines, the latter upon the stools formed by stumps of dead trees, the Tall and the Virginia Cotton-grasses, the Mud Sedge, which was here abundant, Marsh Cinquefoil, Pitcher Plant, Buckbean and Hound-leaved Sundew. The presence of old stumps of considerable size in this zone shows that formerly this part of the bog was more heavily wooded than now, but the cause, other than clearing, of the disappearance of the trees was not apparent. Shoreward, near the margin of the bog, was a zone above the water level, of Blue-Joint Grass, with Silky Willow, and Meadow-Sweet, scattered through it. The River-bank Sedge and Nerved Manna-grass were common here in slight depressions. Still farther shoreward was a well-developed zone of Common Alder which covered the bank nearly up to the zone of cultivation.

The second depression was much smaller than the first, and was in the open shrub stage, of development, i. e., the shrubs, chiefly heath plants, were the dominant types; the entire surf ace was covered by a dense growth of Cassandra and Andromeda. Among these plants there were a few large stumps and numerous small ones, showing that rather recently the shrubs had been dominated by trees, at present represented by a single small White Pine, a Tamarack and some White Birches and Common Alders growing on the hummocks around the stumps noted above. In small open depressions below the general level were sedges and patches of Larger Blue Flag. The water level was generally a little over a foot below the surface in this part of the bog. Shoreward of the shrubs was a zone of lower water level, covered chiefly by the Larger Blue Flag, but with it were the Tussock Sedge, Blue-Joint Grass, Cat-tail, Alder, and several species of Willow. Next to the shore and running up on to it, was a zone of Wool-grass, Nerved Manna-grass, Larger Blue Flag and Soft Bush, which reached up to more than a foot above the surface of the water.

The third depression was elliptical in shape, 30 feet wide by 70 feet long, and had in the middle a small pool of water about 10 feet in length, in which were a few plants of the Yellow Pond Lily and a small patch of Lake Bulrush. Around the pool was a dense growth of Cat-tail covering all of the bottom of the depression except for a narrow zone on the shoreward margin, which was covered by a growth of Wool-grass and slightly above this a zone of the Nerved Manna-grass and Larger Blue Flag.

The fourth depression was covered by a dense growth of Common Alder and Willows.

The bogs in this series show the effects of clearing and burning, in the disappearance of large trees from the larger basins, and of all the trees and plants of the mature bog societies from the smaller ones, so that the cycle of development in these has begun anew with water plants. In the larger ones the building of the sedge mat was apparently not interfered with, but the disappearance of the trees caused the shrub society to expand to a much greater width than would be possible under undisturbed conditions. The series well illustrates the influence which man has locally upon the distribution of plants.

Lake Near Menominee River, South of Norway.

In the same section with these bogs in the cleared and cultivated area, was an interesting kettle-hole lake, located on the terrace of Menominee river. The water of the lake was at the same level with that of the river and was connected with it by a short broad outlet, so that the river, in time of flood, caused a sharp rise in the lake and as abrupt fall when the flood was over. On the zone of the lake bank which was thus alternately covered by water and exposed to the sunlight and the air, was a society of plants which is frequently found in the flood plains of the rivers in the Southern Peninsula, but which is not common in the Northern, where the river swamps have not usually been cleared, and where the mature Tamarack-Spruce-Cedar society is the one in possession of such places, except the more recently formed bars or areas of sediments. The principal plants noted in this society were the Sensitive Fern, River-bank Sedge, Slender Rush, several species of Willows,

Common Smartweed, Canada Anemone, Purplish Meadow-rue, Yellow Water-cress, Meadow-Sweet, Marsh Pea, Upright Yellow Wood Sorrel, Canadian St. John's-wort, Spotted Cowbane, Bulb-bearing Water Hemlock, Swamp Milkweed, Blue Vervain, Hedge Nettle, Cut-leaved Water Hoarhound, Wild Mint, Monkey-flower, Joe-Pye Weed, Late Golden-rod, several species of Aster, Sneeze-weed, and Philadelphia Flea-bane. The soil here was mostly composed of fine silt, or river sediment, and was moist over the entire slope. The absence of characteristic bog plants is of interest and may be due in part to the clearing which has been done, since in a similar bayou-like lake in another place, some bog plants were noted upon the banks of the lake. A view of a portion of this lake and the connection with the river is shown in Plate XII of Prof. Russell's paper, page 57.

Lake Antoine, a Large Basin Beginning to Fill.

This is a large lake with no inlet and small outlet a short distance northwest of the city of Iron Mountain, T. 40 N., R. 30 W., covering parts of several sections. There is little true bog existing around its shores, a large part of which are high and dry, with a rather steep slope. The lake is mentioned here because of a series of small bogs which exist along the north shore in coves on the west sides of points, and behind an island on the northwest side of the lake. The most remarkable of these bogs is the one connecting Pine Island (Plate XXIII), as it is called, with the mainland, making a peninsula of it. The island lies some hundreds of feet from the shore, the entire space between being occupied by the bog, which is prolonged beyond the island on the western end, and has a well-defined cove at the eastern. Upon the bog are two distinct areas of mixed Spruce and Tamarack, surrounded by typical Sphagnum-Cassandra-Andromeda zones. The borders on all sides are covered by a sedge mat, in which the Slender Sedge is the chief plant, forming a belt from 200 to 300 feet wide. The aquatic plants form two distinct zones outside of this; the lakeward one, where examined, made up chiefly of Pondweeds, of which the Common Floating Pond-weed is the most conspicuous and abundant, while next the floating margin of the sedge mat was a zone of varying width, made up largely of White and Yellow Pond Lilies.

The Cat-tail and Dwarf Birch are present in small areas upon the sedge marsh, and the Marsh Cinquefoil forms good-sized patches in places near its margin. The fact that there are two centers of tree growth, and a wide open space extending for a considerable distance between them, would lead to the conclusion that there have been two distinct periods of filling here. The first of these was the time during which the western part was being built up in the shelter afforded by the island, and the other, after the bar thus built had diminished the depth of the water between the island and the shore so much that plants could grow in the water and hold such floating débris and sediment as drifted into the cove thus formed, and this material finally became a center of growth of the bog.

In the coves lying east of the island bog, there are shown several steps in the formation of bogs upon the shores of a large lake. In the first one east of the island, the marginal plant extending over the water was the Slender Sedge, forming a floating bog upon the edge of which were spots of Cat-tail, while upon the bog were some small Spruces and Tamaracks, Alders and Willows, with small areas of Cassandra and Dwarf Birches, and more abundant, the Marsh Cinquefoil, and Marsh Shield-fern. The margin of the mat was entirely free from the bottom, with nearly a foot of water above the surface, and upon this grew small Pondweeds, the Swamp Persicaria, and Greater Bladderwort. In some cases small fragments of the border of the mat, a foot or more across, were free from attachment to it, and formed floating islands, which were moved about by the waves.

In another small marshy area on the west side of a point still further east, the Slender Sedge and the Marsh Cinquefoil were still the dominant plants, but the Lake Bulrush was present in small quantities, and near the landward border of this, as well as the other mentioned above, the River-bank Sedge and the Blue Joint Grass were of frequent occurrence. There were no aquatic plants noted beyond the margin of the sedge mat here.

The location of all of these bogs on the western side of protecting land masses, and the fact that the eastern sides of these were being washed so strongly that the shores were covered by coarse gravel and boulders, with no vegetation near the water's edge, indicate the existence of a prevailing current down the lake upon the north side. This current is most probably set in motion by the westerly winds, blowing the water towards the east end of the lake and heaping it up there, whence it returns to the west end again, in part at least, along the north shore, and the island and points mentioned have small eddies on their western sides, which favor deposition of drift material, silt, etc., carried to them by this westerly current, and this, in turn, encourages the growth of plants which have built up the bogs. No soundings were made here on account of the small size of the deposits and the apparent weakness of the sedge mats, but the water below the margin of the sedge mat was probably at least 6 feet deep.

Sphagnum Bog Near Lake Antoine, Iron Mountain.

On Sec. 20, T. 40 N., R. 30 W., a short distance north of Lake Antoine, was a small bog with some features of special interest, especially in the fact that there were stunted White, Norway and Jack Pines growing in the more open parts, besides Tamarack and Black Spruce, also much stunted. Around the shoreward margin, and especially at the northern end, where its width was greatest, was a dense growth of Balsam, Black Spruce and Tamarack with occasional White Pine forming a

zone of variable width around the open part of the bog. This was irregularly elliptical in shape with a small pond of open water near the northern end, and was covered by a shrub-Sphagnum society, and the partly consumed stumps and other remains of trees, showed that fire had run over the surface at some recent time and destroyed the mature trees. The water level, at the time the bog was visited, soon after a heavy rain, stood from 1 to 2 feet below the top of the Sphagnum mounds among the shrubs, but was above the surface in depressions.

Plate XXV. Western margin of the same lake as Plate XXIV, showing: (1) Absence of aquatic plants; (2) Andromeda, the whitish shrub, growing in and over the water; (3) Cassandra, the darker shrub, forming a mixture near the water, but pure near the shore; (4) Scattered Tamaracks near the water's edge; (5) Norway and White Pine on higher ground.

The water in the pond was more than 5 feet deep off the overhanging edge of the bog, and had no aquatic plants in it except a few plants of the Yellow Pond Lily, which grew so close to the margin that it was not possible to determine whether they grew from under the edge of the bog or not.

The marginal plants here presented a new and most interesting departure from the usual order of advance; the possibility of such a variation had been suggested by the conditions existing at Nathan, and in a more marked degree in the railroad ditches near Faunus. The whole border of the pond was fringed by a zone of shrubs, Cassandra and Andromeda predominating, 10 to 20 feet wide and pushing out into the open water. Of the two species, Andromeda seemed to be the more abundant and more vigorous grower here, frequently occupying considerable spaces and growing out into water several feet deep, for 4 feet or more, with no apparent connection with the bottom. The Cassandra, on the whole, was nearly as frequent in the water as Andromeda, and in one place was seen sending out horizontal, partly submerged branches 6 feet from the shore, in water between 3 and 4 feet deep, but the plant grew taller and larger back from the margin and seemed more thrifty in the dryer parts of the bog, while the Andromeda was neither as abundant nor as thrifty in such places as it was nearer the edge of the water.

After the shrubs had pushed out into the open water in this way and formed a fringe of branches, often other plants would find a foothold with them and would thus build small hummocks. Sphagnum, as would be expected, was one of the first plants thus to take advantage of the chance to extend its range and was to be seen in various places very near the water margin of the shrub growth, but never at it or in open water beyond. With the Sphagnum, a number of other plants were able to grow, including the Small Cranberry, which often followed the Andromeda out into the water without the moss, supporting itself on the stems of the larger and more rigid plants and making a very thrifty growth in such places. Other plants found growing with the marginal shrubs and Sphagnum near the edge of the water were Buckbean, the Round-leaved Sundew and Mud Sedge, but none of these were found advancing beyond the Sphagnum. The association formed a border a foot above the level of the water in its highest parts, but on its shoreward edge the surface was lower, scarcely rising above the water level, over a zone from 10 to 20 feet wide. In this zone, the shrubs were fewer, and there was little if any Sphagnum; the most abundant plants here were the White Beaked-rush and the Mud Sedge, which gave the zone distinct character.

This merged abruptly into the mature Heath-Sphagnum zone, which presented fewer peculiarities, except that in places there were quite extensive patches of the Pale Laurel and where there were trees or stumps, the Sphagnum mounds were built up to a height of 3 feet, or more, above the level of the water. On top of these mounds was found Labrador Tea, which did not grow on the lower ones nor on the sides of the higher ones. The same plant was found in the edge of the well developed Conifer zone, on the shoreward margin of the bog, growing on top of the highest Sphagnum mounds in the shade of the trees.

Other plants in this Shrub-Sphagnum association were the Creeping Snowberry, Small Cranberry, Sheathed Cotton-grass, Virginia Cotton-grass, Few-flowered Sedge, here very abundant, and in the wetter places, near the lakeward border of the zone the Pitcher Plant was very common.

The swamp-conifer border of the Shrub-Sphagnum association was found to end abruptly on the landward side in the thickets of pines which came down the slopes around the bog, except in places where there was a narrow line of Common Alder between them in a shallow trough-like depression, in which also grew the River-bank Sedge. The most common species of pines in the highlands around the depression was the White Pine, but the Jack and Norway Pines were also very frequent and making rapid growth.

In borings near the margin of the lake, the water was found to extend under the mat, to a depth of about 7 feet, below which the peat was coarse and loosely compacted down to 11 feet, where wood was found. At a distance of about 75 feet from the north side of the pond, the peat was compact from 3 feet below the

surface down to about 9 feet, where fine clay was reached. The peat was brownish and rather coarse in texture, until near the bottom, where it became rather finer, but not darker in color.

The fact that this bog had been burned over had undoubtedly disturbed the relations of the plants to a certain extent, but this was not the cause of the peculiar lack of a sedge zone next the water margin, as that would be the area to be least affected by fire. The bog was one of a number of similar ones which, as will be shown later, constitute a distinct type, in some of which, at least, no recognizable disturbance has occurred, except such as may have been brought about by natural forces, operating in the usual and general way, such as periods of prolonged drought, or cycles of wet weather, which occur in all regions at intervals.

Mature Valley Bog Near Granite Bluff.

But few mature bogs were examined in this region because of the lack of variety among them, since they were either usually Tamarack-Spruce-Cedar associations, or more rarely, covered with nearly pure Black Spruce, associated with Sphagnum and shrubs, in which the Spruce was usually very much stunted and more or less scattered. A swamp of this type was examined on Sec. 21, T. 41 N., R. 30 W., near Granite Bluff, on the Chicago, Milwaukee and St. Paul R. R. The swamp occupied a valley and extended a considerable distance in either direction (towards the east as far as the railroad), from the part examined, and, as far as seen, showing the same characteristics.

The Black Spruce was the dominant tree species, but was poor and stunted in appearance, and formed a very thin growth, below which was a heavy covering of Sphagnum, with dense Cassandra and Andromeda. As is usually the case, the surface of the Sphagnum was uneven, built up in mounds 18 inches to 2 feet high above the water level in places, and with relatively bare spots or depressions in others. Upon the mounds were the Labrador Tea, Sheathed Cotton-grass, Three-leaved Solomon's Seal, Pale Laurel and Small Cranberry, and more rarely, the top of a mound was covered by the Hair-cap Moss, which, for the time at least, ends the work of the Sphagnum in upbuilding, since the other moss is able to kill it out, when once it is established upon it. In crossing this swamp from one side to the other, the surface was level and the plants named were the only ones seen, until near the shores. These had formerly been covered by a pine forest, and common plants near the foot of the slopes from the higher ground were Sweet-fern, Hair-cap Moss, Canada, Dwarf and Low Black Blueberries, Bunchberry, Wintergreen, Goldthread and Trailing Arbutus. These plants, except Sweet-fern, also grow in the Sphagnum on the margin of the swamp, while the Creeping Snowberry and Mountain Holly were also found in this habitat. On the other hand the Labrador Tea was found more than 2 feet above the water level, the Cassandra, the Black Spruce and Pale Laurel all were found growing in mineral soil above the Sphagnum, some of them competing successfully with Sweet-fern for space; the fires following the clearing of the pine probably affected the composition of the plant societies of this marginal area in a marked degree, but if so, their effects have nearly disappeared, since the peat along the borders of the mineral soil seemed never to have been burned, and there were few if any charred stumps upon the borders of the swamp. The main effects of the burnings were seen on the higher ground and in the absence of pines from the sides of the valley. If these had been present, the plants requiring much light would have been absent from the marginal area.

The peat in this swamp was about 9 feet deep, half way across the valley, in the places where tests were made, and for about 4 feet from the surface was filled with logs, and the roots and branches of trees and shrubs and such coarse plant débris. Below this depth the structure was finer, but even at the bottom of the deposit it was not well decomposed, although the color was quite dark. Below the peat, the bottom was moderately coarse, whitish sand.

Badwater Lake, North of Iron Mountain.

While this is not a peat-bog lake, some interesting phases of peat formation were observed here which were not found elsewhere, and a brief account of them is not out of place here. Badwater Lake is a small lake about 5 miles north of Iron Mountain, and is situated on Sec. 1, T. 40 N., R. 31 W., in a depression which is connected by a wide, bayou-like outlet, nearly one-half mile long, with Menominee river, so that the water of the lake rises and falls with the river, at least in times of flood. This leaves a space from 3 to 4 feet above the level of the lake in ordinary stages, which is flooded periodically but which receives little silt from the river because of the distance from the stream to the lake. Upon this flooded area was a dense growth of shrubs and such trees as Balsam Poplar, White Ash and Willows. The most common shrubs were the Winterberry, Red-osier Dogwood, Common Alder, various species of Willows, Meadow-Sweet and Sweet Gale, the latter a plant usually found in much wetter places. The bush swamp widens out along the outlet and here, on the margin of the water and growing out into it, were the Creeping Spike-rush and Sweet Flag, making a broad zone of marsh, in which were growing the Marsh Cinquefoil, the Swamp Persicaria and a species of Horsetail. Beyond this unusual association was a zone of Yellow Pond Lily and Pondweeds. At the northern end of the lake the aquatic plants were much more abundant than elsewhere and covered considerable areas. From the relationship of the shrubs to these aquatic zones it would seem that the high water of the spring was able to prevent the shrubs from covering the entire area between the high water and low water marks by drowning them out, but was not able to prevent the marginal zone from occupying a space above the low water or ordinary level of the lake, since the species found there are at all stages indifferent to

prolonged submergence and to considerable drying out as well. The shores of this lake, on the east and north sides, were high and steep and were covered with Norway and White Pine, which ran down nearly to the high water mark.

A Small Lake Near Badwater Lake.

This was about one-half mile south of Badwater lake, in the same depression, and was remarkable in several ways. Unlike Badwater lake, it had no outlet, and was surrounded by a well-developed peat bog, covered by a vigorous growth of Cassandra and other heaths with relatively few conifers except near the shoreward edge and in small groups near the water. The growth of shrubs was much wider on the western side of the lake than upon the eastern and came down into or very near, the water all about the lake. On the north and east sides (Plate XXIV), was a narrow zone of the Slender Sedge, growing attached to the bottom, the water being about a foot deep beyond the thick edge of the turf, which the interlaced roots and stems formed. In a few cases the sedge was sending out long sub-aqueous rhizomes, or horizontal stems, a foot or more beyond the edge of this turf, into the clear water, but, in general, the new branches were growing outward and downward, diagonally over the edge of the turf, making, apparently, for the bottom. Growth in this direction would give a slower advance, but would make the resulting turf exceedingly tough and strong. In spots, outside of this sedge, were masses of Creeping Sedge and of Dulichium growing in the shallow water. In the deeper water were a few plants of the Yellow and White Pond Lilies and of Pondweeds, but these nowhere were abundant. On this part of the shore, fallen logs, which reached across the sedge into the water, were covered with masses of Cassandra and Andromeda on all parts above the water level. Above the sedge zone, and mingling with it on the shoreward margin, was a dense growth of Cassandra with some Andromeda. The Cassandra was very large here and, in places, was unaccompanied by other plants, not even moss growing under its dense shade.

Around the south and west shores where the shrub zone was broader, Andromeda and Cassandra were the marginal and advancing plants, the Slender Sedge appearing only occasionally and then as an intra-marginal plant, 15 to 20 feet back from the water. (Plate XXV). Andromeda, along these shores, formed a dense fringe, reaching out into and over the water nearly four feet, the stems living and retaining their leaves as long as the leaves were above water, which was here more than 3 feet deep in most places, and more than 11 feet, where the mat was widest, with a soft bottom of vegetable ooze. The stems of Andromeda thus submerged did not send out roots into the deep water in most cases, as they did in shallower water, but were kept alive from the shore until they were submerged, or until the dead material beneath had accumulated in sufficient quantity to form a sort of substratum or soil for them. While this is going on, other plants take advantage of the support which the aerial parts of the stems afford and grow out upon them at and above the surface, binding the mass into a firmer structure. The plants thus growing on and around the advancing Andromeda and Cassandra here, were Sphagnum, Creeping Sedge, Slender Sedge, Prickly Sedge, White Beaked-rush, Small Cranberry, Buckbean, Bulb-bearing Water Hemlock, Round Leaved Sundew, Pitcher Plant, Pale Laurel, and Marsh Cinquefoil, and all of these, but especially the sedges and shrubs, help in compacting and binding together the structure started by the Andromeda and Cassandra. A careful examination of this at its outer edge, showed it to be about a foot thick, firm and tough as though very old. A section through it, 6 inches from the margin, gave the following as its composition: A few inches of Sphagnum mixed with sedge root-stocks and leaves of various plants, then a layer of stems of Andromeda and other shrubs, very little decomposed, and mixed with the roots and rootstocks of sedges, below which was a closely interwoven mass of fine, branching shrub roots and the simpler ones of the sedges, which, together, make a very tough, compact substratum. The sedges had apparently bound the stems of the shrubs together by their roots and stems, and while this was being done the shrubs also sent out numerous finely branching roots which assisted in binding the lower parts of the structure together and added to its thickness. Below this turf, at the place where the section was made, the water seemed free from any sediment for some distance from the margin, but, nevertheless, the mat increased in thickness as one went shoreward. In shallow places, Andromeda was sending out long, slender, much-divided roots from the older nodes of the submerged stems, and it is probable that this occurs in deeper water as well, even where the roots cannot reach the bottom.

Patches of the dead stems of the Andromeda and Cassandra, beyond the present water margin and attached to the bottom in 2 or 3 feet of water, seemed to indicate that the water in the lake is higher than formerly, although it is possible that these masses may have been broken off from the margin in some way and have sunk' by becoming waterlogged. The only aquatic plants seen near the border of the shrub mat, where the few plants of the Sweet-scented Water Lily growing very near to the shore in about 3 feet of water.

A small boggy lake on the east half of Sec. 7, T. 40 N., R. 30 W., in which open water covered about 15 acres, presented the following differences in detail from that last described: The shoreward border had a narrow zone of Spruce and Tamarack. There was a Sphagnum-Shrub zone of about 100 feet in width, in which the Pale Laurel, Cassandra and Andromeda were the most abundant plants, but the Buckbean, the Pitcher Plant, and the Tall and Virginia Cotton-grasses were also well distributed over the surface. Andromeda was by far the most active plant of the greater part of the marginal zone, showing distinctly as a pale green border to the open water or even forming islands 25 feet from the

shore. The Cassandra formed occasional intrusions into the Andromeda zone, but was nowhere so abundant. In a small inlet on the margin there were patches of the Slender Sedge growing into the water, but not so vigorously as the Andromeda. The water along the margin of the advancing plants was from 2 to 3 feet deep, and a short distance from the shore there was a narrow, interrupted zone of the Yellow Pond Lily and the Common Floating Pondweed, into which, in some cases, the long stems of the Andromeda were pushing. In no part of the marginal zone of this lake was there any Sphagnum present with the advancing Heaths, the moss, in most cases, being several feet behind the advance of the shrubs.

Bog Near Twin Falls.

The final stages of such bogs as those above, were found in a small, steep-sided depression upon the section line between section 7 and section 12 of the next township west, a short distance from Twin Falls of Menominee river. Around the depression was a good second growth of White and Norway Pine growing down the sides nearly to the level of the bog, which covered an area of a few acres only, and had no open water upon it. In the middle of the bog, however, was an irregularly elliptical area, lower than the general surface and much wetter, which probably represented the part of the water surface last covered. Upon this wet portion the principal plants were low-growing specimens of Andromeda, with relatively few of Cassandra and Pitcher Plant, Virginia Cotton-grass, a slender species of Sedge and a small amount of Sphagnum. In the zone which extended shoreward of this, a hundred feet wide, or more, Sphagnum was very abundant, Cassandra covered most of the surface, reaching a height of 2½ feet, while in the center it was but a foot high. In this zone there were old stumps of trees, while Black Spruce, Tamarack and young Norway and White Pines were scattered over its surface. Labrador Tea was present only around the shoreward margin of this bog, forming a well-marked zone, which reached, at its upper limit, a height of 3 feet above the water level. Cassandra and the Pale Laurel also grew in this zone, and were here associated with the Canada, the Common and the Low Black Blueberries, the Twin-flower, Bunch-berry, Barren Strawberry, Wintergreen, Trailing Arbutus, Sweet-fern, Common Brake, and Clintonia, all plants of the high ground associations in this locality, and abounding on the wooded slopes. Sphagnum was found in this zone growing 2 feet above the water level in the bog. No attempt was made in this tension, or meeting, zone between the bog and upland societies, to find the level of the water in the mineral soil, but it was doubtless not far from the surface. Still, the drainage was sufficient so that in the upper part of the zone there was but a slight accumulation of humus, and the plants were all growing in nearly pure sand. The Common Alder grew up the slopes about this bog to a height of about 10 feet above the water level.

This bog gave additional evidence of the step-like advances which plants make over the surface of the water, in the well-marked zonation about the central depression. Apparently the shoreward border of the depression was for a long time the limit of open water, until the bottom was built up nearly to the surface, and then, in a dry period, the closing-in was accomplished and it is now only a matter of a short time when the surface will be of uniform height above the water level, as in a few years, Sphagnum and shrubs will cover the surface of the depression and fill it up, if the usual order of succession of plants goes on in ordinary course.

Lakes Near Sagola.

Of quite a different type from those just described, was a small lake a few miles south of Sagola in T. 42 N., R. 30 W. The lake was in a slight depression in a sand plain and had been surrounded by a Tamarack-Spruce-Cedar swamp, but the trees had suffered severely from fires, the surface of the swamp had been lowered from the same cause, and there were extensive tracts of Cat-tail growing under the dead trees and in depressions. The water in the lake was shallow, and had a good marginal zone of the Yellow Pond Lily and tracts of the same species scattered over the surface. Bordering the open water, was a zone of Sedge and Sweet Gale, extending to below the present water level, and shoreward of this was a zone of Cassandra and other heaths with Sphagnum in abundance, and still nearer the high ground was the Conifer zone. The Sweet Gale was here apparently the most active species in pushing out from the shore, as it was present along much of the margin, lakeward of other plants, and grew luxuriantly in the shallow water. This shrub grows so tall and is so dense of foliage that few other species follow it closely, so it does not build as firm a structure as other species do. From the depth of the water in which this plant was growing in places, there had probably been a rather recent rise of water in this lake.

A small lake, a quarter of a mile or so north of the one just described, and upon the east side of the road, was quite dissimilar in the plant associations which bordered it, although apparently no deeper. In this there were a few plants of the Yellow Pond Lily, much scattered. There was a very narrow zone of Andromeda with Cassandra, the Slender and other Sedges and quantities of the Marsh Shield-fern mixed with the shrubs. Growing up close to the marginal zone, was an open growth of Black Spruce, Cedar and Tamarack, associated with which were Andromeda, Buckbean, Marsh Shield-fern, Cassandra, the Small Cranberry, Marsh Cinquefoil, Cat-tail, Pitcher Plant, Marsh Bell-flower, Common Alder, Joe-Pye Weed, Wool-grass, Myrtle-leaved Willow, Three-leaved Solomon's Seal, and the Tall White Bog Orchis.

There were no indications here of any recent advance of the marginal zone lakeward, as the trees growing nearly to the water's edge were of good size and were many years old; the narrow zone of Andromeda about and in

the edge of the water was thrifty, but was not making much growth into the water, and this may account for the lack of width, but there was no apparent reason for the slow progress lake-ward, although a more careful study might reveal one.

Bogs and Lakes Near Crystal Falls.

The region about Crystal Falls, especially to the east and northeast, has many extensive swampy and boggy tracts which are covered by peat to a greater or less depth. These were originally Tamarack-Spruce-Cedar swamps now burned or cut over, and many of them have small lakes with more or less of open marsh in them. In general, these deposits, as far as tested, were found to be shallow, only a few feet in depth, but near the middle of the more extensive ones they were often more than 12 feet deep and the peat was of good quality.

In a few examples studied, the plant societies were noted, all, however, showing the effects of fire at some rather recent period in their history.

A Mature Bog: An area 2 or 3 miles north of Crystal Falls was evidently burned over 10 or 15 years ago, at which time the large Spruces and Tamaracks upon it had been killed, but since then a good growth of young trees of the same species has started. The surface was uniformly covered with a dense growth of Sphagnum associated with shrubs, of which the Labrador Tea and Cassandra were the abundant species, with a very little Andromeda, Pale Laurel and Small Cranberry growing with them. The water level was about 2 feet below the surface of the Sphagnum. Of herbaceous plants the Few-seeded Sedge and the Few-flowered Sedge were the most frequent types, but the Sheathed Cotton-grass, Pitcher Plant and Three-leaved Solomon's Seal were somewhat common. The Pitcher Plants were buried deep in Sphagnum, generally only the mouths of the openings in the tubular leaves showing, and as these plants were thriving, an apparent secondary use for the peculiar tubular structure of the leaves is suggested, viz.: that it gives exposure to the light when the leaves otherwise would cease functioning, or nearly so, from being overgrown by the Sphagnum. As it is, the expanded lip of the leaf, which is not covered, and the interior of the tube give opportunity for the light to reach relatively large green surfaces, so that photosynthesis is able to go on without difficulty. It is even possible that the water held in the cavity of the leaf aids in diffusing and refracting the light so that it reaches all parts of the interior of the "pitcher."

This bog represents the general character of the mature phases of bog associations in the region. Of the immature phases, where there were lakes with marshes and bogs about them, a number were seen and a few interesting localities were studied.

Camp Lake, a Partly Filled Lake: Among these, Camp Lake, situated on sections 27 and 34, T. 44 N., R. 33 W., was visited, and found to have a wet sedge marsh around it, but next to the water was a narrower zone of Cassandra and Andromeda, which, as usual in cases where this occurred, was pushing out over and into the water. The Cassandra stems were extended horizontally more than 3 feet, and those of the Andromeda often 4 or 5 feet, into water at least 3 feet deep.

Plate XXVI. Old growth of stunted Black Spruce at Balsam, Iron County. The few Tamaracks are somewhat taller and show more open tops. The open water in the foreground is a ditch cut by the railroad, along which the overhanging Cassandra may be seen.

Under the margin of the advancing shrubs began a well-developed zone of Yellow Pond Lily, which was 50 or more feet broad, and beyond this was an aquatic northern form of Bur-reed growing in the deeper water, and forming a well-marked zone, lakeward of the Pond Lily zone. Associated with the shrubs were the Slender Sedge, Marsh Cinquefoil, Pitcher Plant, Sphagnum, Marsh St. John's-wort, and the Round-leaved Sundew. The Sphagnum was growing upon the established turf a foot above the water level, and did not extend out into the water among the advancing shrubs. In the sedge zone were patches of Cassandra, extending shoreward nearly to the bank, and in many cases the remains of shrubs, charred by fire, showed that that destructive agent had recently modified conditions in this area. The most common plant of the sedge zone was the Bottle Sedge, but with it were the Slender and Mud Sedges, the Blue Flag, Wild Calla, Marsh Cinquefoil, and Sphagnum and Hypnum mosses below them in the wetter places. The conspicuous plant of this association was, however, the Bottle Sedge, which grew very tall and, with its yellowish foliage and large fruiting spikes, made a striking appearance.

Shoreward of the sedge zone was a well-defined zone of Blue-Joint Grass, several feet wide, which was above the water level and which landward merged abruptly into the plant society of the burned over pine lands.

The unusual relation of the sedge and shrub zones here, and the fact that the shrub zone is higher than the surface of the sedge zone, may indicate that a severe fire, at a time when the water in the lake was low, destroyed much of the peat which had accumulated,

leaving only a narrow border near the water in which the peat was too wet to burn; this was the nucleus of the present growth of shrubs at the margin of the lake, and in the depression behind it, the sedges have since established themselves and the water level has risen until a wet marsh is the result. The fact that the lake lies in a region which has been cleared of pine, and that evidences of fire were seen below the water level at the time when the lake was visited, makes the hypothesis advanced seem the more reasonable.

Spring Bog Near Camp Lake: Camp lake is a partly filled depression in an elevated portion of a dissected gravel plain and has no outlet above the surface, but about one-eighth of a mile to the west is a steep slope, at the bottom of which, 50 feet below the level of the lake, is a large spring-bog, covered around the margin by an old growth of Cedar, Tamarack and Spruce, with an open bog and small lake in the middle. This is fed by a great number of powerful springs, and is apparently one of the outlets for the water of the lake, although the porous nature of much of the higher land in the vicinity would not preclude the supposition that these are ordinary seepage springs, if it were not for the large number which are to be found over the bottom of the depression and the proximity of the lake without other outlet. The pool formed by the union of the waters of these springs was of considerable size, surrounded by a floating or quaking bog, bordered by stools of the Bristly Sedge, together with quantities of the Marsh Shield-fern and the Sweet Gale. The latter bordered the shallow water of the pond, in which were some plants of the Yellow Pond Lily and many small islands of Sweet Gale. Shoreward of the Sedge-Sweet Gale zone, was a broader one, covered by Sphagnum to a depth of a few inches, where the water level was 4 inches below the surface; and growing in the soil thus formed were Buckbean, Small Cranberry, short, small plants of Andromeda and Cassandra, Cotton-grass, Pitcher-Plant, Marsh Cinquefoil, Mud Sedge, Marsh Shield-fern and several Orchids.

This marsh gave place, landward, to a slightly dryer one, with deeper Sphagnum and larger shrubs in which were clumps and individual trees of young Tamarack. The herbaceous plants here were several species of sedges, among which Magellan's, the Lesser Panicled and the little Prickly Sedges, were the most noticeable, Buckbean, Pitcher Plant, and Orchids, here very abundant, of the three species, the Tall White Bog Orchis, the Tall Leafy Green Orchis and Ladies' Tresses. In parts of this area were beds of Andromeda nearly buried in Sphagnum.

Still nearer the high ground was the mature Conifer zone, rather open on the pond ward side, but dense farther in shore. In this, the Sphagnum had built up mounds, in places from 2 to 3 feet high. At the latter height, however, the Hair-cap Moss was almost invariably on top, and where it was not, the Reindeer Lichen replaced it. On the tops of these mounds, growing among the mosses, were Labrador Tea, Bunch-berry, Creeping Snowberry, Twin-flower, Goldthread, Marsh White Violet, Fringed Polygala, Mountain Maple, young Tamarack, Common Horsetail, Goose grass, Clintonia, Bed Raspberry, Three-leaved Solomon's Seal, and Small Bishop's-cap.

Between the hummocks built up by the Sphagnum around shrubs and tree roots, often in the water, were found Wild Calla, Marsh Marigold, Swamp Saxifrage, Pitcher Plant, Round-leaved Sundew, Buckbean, Small Cranberry and Marsh Shield-fern. In parts of this zone, where it was not deeply shaded, Sweet Gale grew with Labrador Tea and Cassandra upon the stools about the roots of trees, 2 to 3 feet above the water level, where Sphagnum was giving place to Reindeer Lichen, thus growing at the greatest distance of any of the marginal shrubs above the water level, as well as below it.

The water in the springs was cold and clear with an irony taste, but the outlets were often clogged with dense masses of Algae, through which the water bubbled up and flowed away in small streams. Around these outlets were sometimes beds of Hypnum moss, with which was usually growing quantities of Smaller Bur-Marigold. The spring outlet-streams were usually lost in the marsh, before reaching the pond, but a few of the stronger ones persisted until they reached it; the surface of the bog sloped slightly from the older timber zone to the pond and apparently had been built up as the result of peat development following the constant outflow of water over the surface, which created conditions favorable to its development. This and a similar bog near Runkle Lake, about a mile and a quarter east of Crystal Falls were the only spring-formed bogs visited. The Runkle Lake bog was also caused by springs which were the only outlet of the lake, but was more nearly of the ordinary type of mature Tamarack-Spruce-Cedar association, such as has been frequently described.

Bogs Near Amasa.

A River-Flooded Lake: The point farthest north which was reached in this region was the town of Amasa, T. 44 N., R. 33 W., where on section 5, a small lake near Little Hemlock river, was examined.

The marginal zone here was made up entirely of Sweet Gale, which was advancing over the water, and the Tussock Sedge, shoreward, of which was a continuous zone of Cat-tail, Sweet Gale and Common Alder, sometimes mixed and sometimes in dense patches of a single species. Still nearer the shore was a marsh in which the Tussock Sedge was the dominant plant and had built up tussocks to a height of more than two feet, with nearly dry ground between. Some Sweet Gale grew between the tussocks and upon them were thrifty plants of Cassandra and Blue-Joint Grass. The plants, beside the Sweet Gale, which were found growing with the Cat-tail, were Sphagnum, the Marsh, Willow-herb, Marsh Shield-fern, Marsh St. John's-wort and Marsh Cinquefoil. Under dense patches of Sweet Gale in this zone, there was some Sphagnum and a few small light

colored plants of Marsh St. John's-wort and Touch-me-not. The water level in this zone was about 6 inches below the surface of the quaking turf-like structure upon which the plants were growing.

The shoreward marginal zone was made up chiefly of shrubs, of which the Sweet Gale was the most abundant, but the Common Alder, Buckthorn and Cassandra were common, while upon the tussocks of sedge were occasional plants of Labrador Tea. Between this zone and the high ground vegetation, there was formerly a zone of conifers, as charred stumps showed, but when visited no trees existed there. The lake was in a gravel plain and was formerly surrounded by a pine forest.

The close connection of this lake with the river suggests the probability of periodical flooding of the marginal zone, which in turn, may account for the mixed character of the associations of the various zones and the wide distribution of the Sweet Gale.

A Mature Bog: On section 6 of the same township, was a well preserved bog of the mature type, which was characteristic of the bogs of the vicinity. The surface was covered by a dense growth of Sphagnum, which was from 1 to 1½ feet deep, and the water level from 1½ to 2 feet below the surface of the growing moss. The trees were chiefly stunted Black Spruces, which were mixed with a few Tamaracks. The shrubs were Cassandra, the dominant species, Andromeda and Pale Laurel, common, and Labrador Tea rather frequent, but growing best on the tops of the Sphagnum knolls and on stumps and roots of trees, and it was the only shrubby heath on the dryer ground of the margin, except the Blueberries which were here associated with it. The herbs growing in the Sphagnum were Pitcher Plant, Three-leaved Solomon's Seal, Sheathed and Virginia Cotton-grass, Three-seeded Sedge, Creeping Snowberry; Mountain Ash was abundant near the shoreward margin with the Labrador Tea. The peat here was full of roots and fallen logs and about 10 feet deep where tested.

Spruce Bog at Balsam.

At Balsam station (section 13, T. 44 N., R. 33 W.) the junction of the Amasa branch of the C. & N. W. R. R. and the Superior division of the C. M. & St. P. R. R., was a fine example of a Spruce bog. (Plate XXVI.) The Spruce was much stunted and rather sparsely distributed over the surface, with a few small Tamaracks mixed with it. The surface of the bog was covered with a Sphagnum-Heath association with Cassandra the dominant plant, and Andromeda and Pitcher Plant abundant.

Over much of the surface the water was less than a foot down, but in places where the Spruces were grouped together the Sphagnum had grown up around them to a height of more than 2 feet above water and in such places, Labrador Tea and Canada Blueberry were frequent on the tops of the hummocks. On some of these hummocks the Hair-Cap moss had established itself and frequently the Reindeer Lichen as well. Besides the plants mentioned, the general bog association included the Small Cranberry, the Virginia Cotton-grass, Three-leaved Solomon's Seal, and Few-flowered Sedge. The Spruces were many of them infested by the parasite, the Small Mistletoe, and there were hundreds of dead Spruces which seemed to have been killed by this pest, while many of the living ones were distorted by its attacks, showing the characteristic "witches' brooms," due to abnormal branching. In the ditches beside the railroads were found Cassandra and Andromeda frequently nearly filling the ditch, while in some places Sphagnum was growing abundantly as an aquatic, one of the very few observations of this character made during the entire trip and apparently a rare occurrence, even in similar situations. Where holes which reach below the water level are cut in the peat upon which Sphagnum is growing, as in the case of these ditches, the moss wall sometimes establish itself in the water. That it does not always do so, or even usually, may be due to the fact that the species which can live in the water are not present when the holes are cut.

In places where fire had burned off the surface layers of moss and shrubs so that the water level was near the surface, the Few-flowered Sedge and Pitcher Plant were prominent, but the other plants of the Sphagnum-Heath association were usually present with them and apparently would soon surpass them.

This body of peat, while not of great extent, is near others and most favorably situated for exploitation in connection with the iron mines at Amasa and Crystal Falls. It is, however, rather shallow, averaging about 6 feet in depth where tested, and was only 7 feet, near the middle. The peat was rather light colored and not well decomposed.

In several places, "islands" rising above the general surface were noted. Some of these were burned off and showed a formation of mineral soil, with 2 or 3 feet of peat above the water level. On such islands Labrador Tea grew with great luxuriance. The railroad grades were, ill part, covered by grasses, but in places the bog heaths, especially Cassandra, had established themselves upon them, and the Canada Blueberry was often a dominant plant near the top of the 4-foot gravel embankment.

Sand Plain Lakes and Bogs South of Crystal Falls.

In the extensive sand plain, south of Crystal Falls are a large number of depressions, some of which, have bogs in the mature stages, while others have lakes with scarcely a trace of filling. Some of these unfilled lakes are shallow, while some of the partly filled ones are very deep off the edge of the boggy margin, so that it seems apparent that depth does not control the rate of filling, although if other things were equal this would be the

case. The following examples from this sand plain region illustrate this interesting point, as well as show the conditions of peat formation existing there.

In the vicinity of Clara Lake, T. 42 N., R. 32 W., the open plain is rolling in character with occasionally a rock hill a hundred or more feet above the general surface. The prevailing flora is that of burned over pine lands, and the chief species of pines here are the Jack and Norway, while Scarlet Oak, Poplars, Sweet-fern, the low Blueberries and various dry ground grasses and sedges constitute the greater part of the rest of the flora.

A Rejuvenated Sedge Bog Near Clara Lake: In a small depression, a mile or so south of Clara Lake, the water was about 3 feet deep when visited, and in it was a dense mass of Slender Sedge covering the deepest part of the pond. Surrounding this was a well marked zone of Bottle Sedge, growing in water 1 and 1½ feet deep, shoreward of which was a zone of Tall Manna-grass and Blue Flag. From the water's edge up to about 2 feet, above it, was a zone of Willows and Meadow-Sweet, and above this, Blue-Joint Grass, Sweet-fern and Tall Blackberry formed a well marked zone around the depression. This was an unusual combination, and was probably the result of rather recent disturbance of plant relations by fires which destroyed the older association, and the ground was then occupied by the plants nearest at hand. There was no indication that the bottom of this depression, shallow as it was, had ever been filled with peat.

Two Shallow Lakes in the Sand Plain: In a shallow lake on sections 21 and 22 of the same township, was a more usual association, but one not frequently observed in the region: the Yellow Pond Lily formed a wide zone, in which were some Pond-weeds and White Pond Lily plants. The shoreward margin of this, was marked by a narrow zone in which the Lake Bulrush was the dominant plant, but growing with it, the Creeping Spike-rush was abundant in places, as well as the Cat-tail. Near the water's edge, but growing in it, were small areas of Dulichium. At the water's edge or a little below it was a well marked zone of chiefly Sweet Gale, but in places the Slender Sedge and Tussock Sedge replaced it. This zone of Sweet Gale extended up to about 3 feet above the level of the water, where it was replaced by an association in which the Common Alder was the most notable plant. In the Sedge areas were Marsh Cinquefoil, Marsh St. John's-wort, Marsh Bell-flower, Wild Mint, Great Water Dock and in the higher parts of such places were some Sphagnum. Cassandra formed a slight admixture with the Sweet Gale in a few spots. This lake, with abundant aquatic vegetation, was characterized by the narrow zone of marginal plants, which had made no progress away from the shore, so that there was no border of peat.

Another apparently very shallow lake was visited 2 or 3 miles southwest of the last one, which, while it was scarcely more advanced in the filling process than the one above described, was of sufficiently different character to warrant brief description. It is located in a region of steep, high, sand and gravel ridges, which were formerly covered by a dense forest of Norway Pine, now replaced by shrubs and Poplars with a few small pines. In the lake were scattered plants of the Yellow Pond Lily, but nothing approaching a zonal development. The margin of the pond had a border of Cassandra and Andromeda from a few feet to a few yards wide, both species reaching out into and over the water, the latter rather more frequently than the former. In this border were some Spruces and Tamaracks in the part nearest the shore and Sphagnum, with its surface 1 to 2 feet above the water level, was constant in all the lakeward margin of this zone, and in many cases was growing out beyond the limits of the shrubs upon fallen logs, but was nowhere seen in the water in such places. In this Sphagnum-shrub bordering zone were the Buckbean, Pitcher Plant, and Round Leaved Sundew near the water level, and back among the trees on higher places with Cassandra were the Small Cranberry, Labrador Tea, Creeping Snow-berry and Choke-berry, here noted for the first time in a bog in this region. These plants ascended the slope to a height of about 3 feet above the water and were competing with the Canada and Low Blue-berries, and Common Brake for the ground. In this tension zone were also found the Mountain Holly, and the White and Norway Pines.

Deep Lakes Near Stager: South and west of Stager, were two remarkably deep lakes of the tarn type separated by a high, narrow, steep-sided gravel ridge, on which the wagon road runs. The slopes of this ridge were continuous with those of the bottom of the western lake, which was very clear and deep, and apparently also with those of the eastern one in which the water was also very deep. The western lake had only a very narrow marginal zone of Cedar and accompanying plants, and in one place a small area of Slender Sedge. These plants had not begun to advance over the water at any place and the steeply sloping bottom could be seen to a depth of 25 or 30 feet below the surface, and water logged trees and similar débris distinctly seen lying on the slopes.

The bank upon the eastern side of the road was even steeper than that on the western, nearly perpendicular in one place, for several feet, and apparently ran without a change of slope into the lake, which was somewhat larger than the other. About this lake, however, there was a well developed heath bog, several hundred feet wide, all around the open water, in which Cassandra and Andromeda were the dominant plants, except for several rods of the shoreward margin where there was a well developed Tamarack-Black Spruce zone.

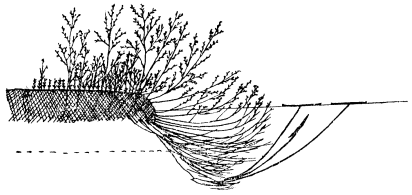

Figure 13. Diagram showing way in which Andromeda and Cassandra built out a mat over the water in a lake near Stager.

The Andromeda and Cassandra were growing out from the edge of the tough mat, somewhat as shown in Figure 13, over and into the water to a distance of 3 or 4 feet, where the water was so deep that the bottom was not visible, although the water was sufficiently clear to allow the light to penetrate it for more than 10 feet. There were large masses of submerged branches and twigs of the shrubs in the water below the living ones and apparently it was these which furnished the substratum upon which finally the shoots, sent out from the margin of the mat, took root, and gained sufficient stability to permit other plants to grow out upon them. Growing out from under the edge of the fringe of partly submerged shrubs, from an invisible base of attachment, which may have been the lower part of the mass of branches just described, were a few plants of Yellow Pond Lily, but nothing like a zone of this species was present. There were no plants of other species growing upon the partly submerged shrubs, except a few plants of the Small Cranberry, but where the turf was established, Sphagnum was present, and with it the Small Cranberry was very abundant and associated with the Few Flowered Sedge, Pitcher Plant, Tall Cotton-grass, Pale Laurel, Three-leaved Solomon's Seal, Scheuchzeria and Buckbean. Cassandra, Pale Laurel and Labrador Tea were the chief shrubs of the conifer zone.

These two basins were the deepest small ones visited, and no cause was apparent why the larger one should be so far advanced toward filling, or at least toward being covered, while the smaller one, with identical structure and conditions should not have begun to fill, except that the proper plants had not become established about it. Neither was there any assignable cause why this deep lake should have so far advanced in developing into a bog while the much shallower ones described above, with the same plants about some of them, had made little or no progress in such development. In the case of the deep lakes just described there had been no severe fires about them in recent years, since there were mature living trees of several species about their borders.

Mature Bogs Near Mary Lake: In the vicinity of Mary Lake, T. 42 N., R. 31 W., also in the gravel plain region, two mature bogs were visited. The first of these was a heath bog, highest in the middle, with dense growth of Cassandra and Andromeda on it, around which were either stretches of open water, or a broad zone of Slender Sedge and Bottle Sedge, with water a foot or more deep, while the landward margin from the water level up to 3 feet above it, had a zone of Cassandra again, here growing in sand with Meadow-sweet, Low Blueberry, Bearberry, Twin-flower and other plants, some of which are important members of the Norway Pine association of the surrounding barrens.

A short distance south of Mary Lake was a large depression in which was an extensive sedge marsh, the only one seen in the entire expedition, in which the Few-seeded Sedge was the dominant plant over so large an area. This was apparently a rejuvenated mature bog in which fire had swept away the plant association of the mature stages and at the same time lowered the surface of the peat to the water level; thus conditions favorable for the growth of the sedge were developed, and as the plant is frequent in mature bogs in the more open and moister places, where fire might not destroy it, it may have spread from these places as centers until it covered the whole area. This would be especially the case if there were, at the same time, increase in the rainfall sufficient to make the burned-over peat very wet.

Evidence of burning existed in this bog in the form of numerous charred tree stumps, with more or less exposed roots; these served as the nuclei of islands of Cassandra and Sphagnum. Towards the middle of the marsh the Cassandra became more generally spread over the surface, and here there were stunted Black Spruces and Tamaracks.

Around the Cassandra and other shrubs, and the trees, Sphagnum was usually found building up the surface a foot or two above the water level. This moss was also abundant in the shallow water of the Sedge marsh, rising but an inch or so above the surface, or at most only 6 inches. Aside from the Cassandra plants and groups of Andromeda, Dwarf Birch and the Myrtle-leaved Willow were the centers of Sphagnum islands.

Growing in the water with the Few-seeded Sedge were the Mud Sedge, the Slender Cotton-grass, Scheuchzeria, and Flat-leaved Bladder-wort, while the Pitcher Plant and Small Cranberry were occasionally found upon the Sphagnum islands. An unusual association was found in places, in the wet, shoreward margin of this bog, where the Three-seeded and Little Prickly Sedges and Wool-grass formed groups of low hummocks. Still shoreward of this, above the water level and outside the bog, growing in the sand, was a zone of Alder, Dwarf Birch, Pale Laurel, Labrador Tea, Choke Berry and Mountain Holly. These plants were all thrifty and were noticeably larger and stronger than those growing in the bog and grew as much as a hundred feet from its margin. The Labrador Tea was the most abundant of the heath plants here, and in many places covered the ground for a distance of from 50 to 100 feet from the edge of the bog and successfully held it, in competition with the usual sand plain vegetation, here represented by Norway and Jack Pines, Beaked Hazel-nut, Tall Blackberry, Prairie Willow, Sweet-fern, Low and Canada Blueberries, Trailing Arbutus, Bunch-berry, Common Brake, Clintonia, Cow Wheat and Hair-cap Moss.

The occurrence of Labrador Tea in this association of well known dry ground plants, is exceedingly suggestive as to its power to resist drought; in the observations made up to this time it had been noted that this plant was practically always found in the dryest parts of the bogs in which it grew, but this was the first observation made, and amply confirmed by later ones, where it was a member in good standing of the drought-resisting or xerophytic association of the sand plains, away from true bog conditions.

Plate XXVII. Spruce—Shrub—Sedge-bog near Lake Mary. The dense growth of Black Spruce is shown on the left, the small remnant of open water to the right of the center. The hills around have White and Norway Pine, or stump land, with low shrubs and herbs.

The climax of this series of sand-plain bogs was about a mile west of Mary Lake, in a large depression in a rolling part of the sand-plain. (Plate XXXII.)

In one place, to the south of the center, was a small pond of open water, very shallow with a bottom of finely divided peat in which were growing the White and Yellow Pond Lilies and the Water Shield. This pond presented a peculiar problem, in the fact that the borders of it seemed to have been broken up rather recently, possibly by the wallowing of bears or trampling of deer so that its area had increased. The margin was irregular and in places in the water there were masses of dead shrubs with tops standing above the water, not as islands, but as if attached to irregular fragments of larger masses or the submerged remains of the former shore. Around the present margin was a zone of bare peat several feet wide, a very unusual condition, extending nearly around the entire pond. Back from this, was an association very rich in species for this zone, in which Sphagnum was very abundant and covered the surface. Growing in it were Pitcher Plant, Slender and-Virginia Cotton-grasses, Mud Sedge, Scheuchzeria, White Beaked-rush, Few-seeded Sedge, Small Cranberry and small plants of Cassandra and Andromeda. This was surrounded by almost pure Black Spruce growth, the trees stunted and scattered, in which Sphagnum had raised the surface in mounds, in places nearly 3 feet above the water level. Here the shrubs and other plants were in about the association usually found in such bogs, but in much of the open space between the trees, the Few-seeded Sedge was rather more abundant than was usual in such places. Towards the shore, the Sphagnum was not as deep, the water was nearer the surface and the Spruces had been killed by fires. In this zone the Few-seeded Sedge and Cassandra were the chief plants over considerable areas, in the wetter places the sedge, and in dryer ones the shrub predominating. The amount of peat in this bog was large, as the depth was over 10 feet in most of the area, but it was very wet, so that in many places near the margin the mass could be shaken without much effort. In dryer times it is probable that there would be less percent of water in the peat, as the water level sank, but it is doubtful if such a deposit could be utilized under present conditions on account of the cost of preparing it for fuel.

Bog Near Iron River.

The only bog visited in the vicinity of Iron River, was found about a small lake 2 miles south of the town. The lake, or pond, was very shallow, showing bare flats in many places, with a peaty bottom and was full of small islands, covered by Broad-leaved Arrow-head, Bristly Sedge, and Creeping Spike-rush. The surface of the water was covered in most places by Pondweeds and Yellow Pond Lily, with considerable of the Arrow-head in shallower places. The marginal zone was from 3 to 5, up to 10 feet wide, in places examined, was easily shaken, and was occupied almost exclusively by sedges, of which the Slender Sedge and the Creeping Spike-rush were the ones making most rapid advance over the mud bottom. The Tussock, Bristly, River-bank, and Porcupine Sedges, were all more or less engaged in forming tussocks along the margin and in this way were aiding in extending the zone. In a few places the Lake Bulrush was established near the shore, but covered no large areas. Dulichium, Buckbean and Marsh Cinquefoil, and in a few places, Sphagnum were also forming small patches here and there in this zone, but Sphagnum was quite rare, and the other plants unimportant. Shoreward of this zone was a much broader one of Sphagnum, with which were growing Tamarack, Common Alder, Cassandra, Pale Laurel, Marsh Cinquefoil, Small Cranberry, Pitcher Plant, Blue Flag and several sedges. Still farther shoreward, was a dense growth of Cassandra, and a zone of Sedges, Andromeda, Pale Laurel and Meadow-sweet growing with thin Sphagnum ground-cover. This portion was practically all above water level, so that the peat was firm and dry, even in paths a foot or more below the general level of the moss. The surface sloped gently upward to higher ground and grew more and more dry, but the heaths persisted into a zone where the Hair-cap Moss replaced the Sphagnum almost entirely. In a part of this, the Pale Laurel was exceptionally abundant and vigorous, while Cassandra and Andromeda also were growing better than usual. With these shrubs were the Marsh Cinquefoil, Sedges, Blue Flag, and some other species. At the top of the slope was a zone of Blue-Joint Grass and still higher a thin growth of Poplars. Fire had swept over a part of this bog, but so long ago that most of the plants had nearly reestablished themselves, although clearing had undoubtedly increased the importance of the shrub and herb societies, above the marginal zone. The fact that the surface of the bog sloped, and that the water was so shallow, suggested a recent lowering of the water by ditching, but no time was available to find out whether this had been done.

Mature Peat Bog North of Bessemer.

During a two days' stay at Bessemer, a trip was made to a large peat bog on Eight Mile Creek, north of the city. This was one of the most interesting bogs visited, in spite of the monotony of the conditions, for it had never been disturbed by fire or by man. The swamp or bog was covered by a growth of Black Spruce with some Tamaracks along the borders and occasionally in other places. The Spruce trees were of small size, slow-growing, as shown by the distance between the whorls of branches and were covered with lichens. The ground was usually covered with Sphagnum and shrubs but in many places the shade of the trees or shrubs was so dense that apparently the moss was unable to grow. Along the creek Cassandra grew very luxuriantly, reaching a height of about 5 feet and forming such a dense cover that nothing was growing under it, although there was a sparse growth of old Tamaracks overtopping it. At a distance of from 8 to 15 rods from the stream the Cassandra was less dense, and Sphagnum and Black Spruce became the most noticeable plants. The Spruces were irregularly grouped with larger or smaller open spaces between them, thus forming a somewhat open stand. In the denser shade of the clumps there were practically no plants with the Sphagnum, when this was found in such places, except the Creeping Snowberry, which was frequently found alone, covering the ground with its delicate tracery. The more open places between the denser clumps of Spruce, had an association in which, besides Cassandra, were Labrador Tea, Canada Blueberry, Pale Laurel, and, rarely Andromeda; Small Cranberry and Creeping Snow-berry often formed dense mats over the Sphagnum. The Labrador Tea and Laurel had very broad and large leaves in this locality, probably an adaption to the reduced light, since plants in more open places, had much smaller, narrow ones. The herbaceous plants noted here were Stemless Ladies' Slipper, Indian Pipe, Wintergreen, Three-leaved Solomon's Seal, Pitcher Plant, Few-flowered and Few-seeded Sedges. This association occurred with slight variations as to the number of individuals of the given species, according to the depth of the Sphagnum, or the amount of shade developed by the trees, over wide areas in this bog, in fact in every part visited.

The peat was tested in several places; the first section gave the following: Sphagnum 1 foot; coarse, poorly decomposed peat with roots of trees and shrubs, 1 foot; below this the peat was finer grained and compact, with an abundance of sedge roots and fragments of root-stocks for 2 feet; at 9 feet fine clay 3 inches, below which were sand and gravel. Water at 1 foot from the surface. (Fig. 14.)

Another test showed the Sphagnum to be from 8 to 19 inches deep, abruptly changing to compact, rather coarse, dark-brown peat, with abundant sedge remains, to a depth of 6 feet, then sand. The water level averaged 1 foot below the surface here. At a third station, a long distance from the second, the Sphagnum was about a foot thick in the lower places and nearly 2 feet in the higher, where it was growing about shrubs, etc., i. e., variations of the surface were largely due to the variation in depth of Sphagnum. Below this the peat was rather coarse and dark colored, to a depth of 9 feet, with 5 inches of fine clay at the bottom and then sand. The water level here was about as it was in the other holes.

Figure 14. Section of Bog north of Bessemer.

a. Sphagnum and shrub remains.
b. Sedge and shrub remains, poorly decomposed.
c. Sedge roots and fine material.
d. Structureless peat.
e. Clay and sand.

It is evident from these borings, and numerous other tests here, that Sphagnum is only a superficial plant, which is of recent introduction upon the surface of the bog, for Sphagnum remains do not appear in the more compact peat below the bottom of the moss. The peat formed by Sphagnum is so characteristic, so different in texture and color from that formed by any other plant, that it is not to be mistaken, when once it has been examined, for anything else, and peat with any considerable amount of the plant present, is very readily recognizable. The tests made point to the fact that this deposit was built up largely by other plants than Sphagnum, and that for a considerable time before the Sphagnum established itself, the sedges were abundant and were efficient in building up the surface of the bog. What the plants were which built up the lower parts of the deposit, was not determined, but there was no indication that they were sphagnum. In this deposit of peat, the plants seemed to have followed the same succession and developed the same association as the climax, as those which were examined further south, and in most respects the flora would be identical with that in spruce swamps throughout the region studied, but it would be very rare in more southern parts of the state to find such an extensive development of peat in so shallow a depression, if any were formed in it at all.

Lakes and Bogs in the Keweenaw Peninsula.

For the sake of comparison, and to determine, if possible, whether any different factors or plants entered into the formation of peat bogs in the northern part of the Northern Peninsula, from those found in the southern part, a brief reconnaissance was made in the region

about Houghton, during the first week in September. A trip was made to the Winona mine near which there were several small lakes, partly filled, and some bogs representing completely filled ones.

Bog Near Winona Mine: The first locality visited was a small bog in a heavily wooded country, the chief high-ground trees being Yellow Birch and Sugar Maple. The bog was in section 32, T. 52 N., R. 36 W., was elliptical in shape, with a distinct zonal arrangement of the plants about it and had in the center an open marsh in which sedges and shrubby heaths were about equally abundant. This area of open marsh was about 250 feet long by 150 feet wide. The water level was about 15 inches below the surface of the higher parts of the mat of vegetation, and a foot or less in the lower ones. Sphagnum covered the surface and was the cause of its elevation above the water level, and with it, the following plants were found: Cassandra, Andromeda, Pale Laurel, all rather small and low, the Andromeda more common here than in other zones, the Small Cranberry, Pitcher Plant, the Few-seeded, Mud, and Few-flowered Sedges and Cotton-grass. Shoreward of this area was a zone of Black Spruce and Tamarack, the former dominant, with the following associates: Sphagnum, Labrador Tea, Cassandra, Pale Laurel, Andromeda, and on elevations of the surface, with Labrador Tea, the Canada Blueberry. The herbs here noted were Magellan's Sedge, the Sheathed and Virginia Cotton-grasses, and Pitcher Plant. This zone gives place in turn, to one in which the Spruce is wanting, except very young plants, and the Tamaracks are very large. With these were young Bed Maples, White Pines and Yellow Birches, and besides most of the shrubs and herbs of the other zones, Creeping Snowberry, Three-leaved Solomon's Seal, Three-seeded Sedge and Cinnamon Fern were found, the last, the most abundant herbaceous species and forming a striking zone by itself on the shoreward edge of the old Tamarack association. Between the Fern zone and the high ground was a slight depression, without standing water, a marginal fosse or ditch, in which grew the Blue Flag, Wild Calla, Three-seeded Sedge, and Sphagnum.

In the open part of the bog the water was about a foot below the surface of the growing Sphagnum, and at 1½ feet, shrub remains were few and the amount of Sedge and Cat-tail débris increased to a depth of 2 feet, when the peat became very watery, and was too liquid to gather samples from, to a depth of more than 10 feet.

In the Spruce zone, the water level was about 1 foot below the surface of the moss, and the turf was composed of shrub and moss débris to a short distance below the water level where the material changed abruptly to Sedge and Cat-tail rootstocks and leaves. Below this the peat remained fibrous, light colored, and very watery to a depth of more than 10 feet. The water level was nearly 2 feet from the surface in the old Tamarack zone and the surface was much dryer, especially around the bases of trees, and it was on these elevations that Labrador Tea and Canada Blueberry were growing most luxuriantly.

The outlet of this bog was a small, badly-clogged brook flowing through a peaty valley, and it seemed quite probable that, as the peat had accumulated in the valley, it had slowly checked the outflow from the basin and thus raised the level of the water in the basin and this in turn had tended to raise the surface of the bog by encouraging the growth of the peat-forming sedges and other plants. It was apparent from the study of sections that the Sphagnum had only recently, compared with the total age of the bog, established itself upon the surface of the deposit which had been covered by sedges and Cat-tail.

Lake Near Winona Mine: On section 33 of the same township was a small lake surrounded by steep banks covered by a Birch and Maple forest, except near the foot of the slopes where Hemlock, Balsam and Yellow Birch were the important trees. The lake is about twice as long as wide, and at the north end has a small bog, which was rather hastily studied. In the water along the margin of the bog were patches of Yellow Pond Lily and a Pondweed and in other places, the Submerged Bur-reed, a species of Arrow-head and the Greater Bladderwort were noted.

The chief plants along the water margin were Cassandra and Andromeda, which were generally advancing the turf by the growth of partly submerged branches reaching over and into the water. The plant which here was most closely following the shrubs was the Blue Flag, a very unusual marginal plant in the region which had been traversed up to this time, in fact it was rather rare in the bogs at all, except occasionally along the shoreward margin. Here, however, it made an abundant growth among the shrubs on the edge of the turf nearer the water than any other plant except the Small Cranberry, which was occasionally found growing over the water upon the shrubs.

Immediately shoreward of the Blue Flag zone was Sphagnum, which, however, was unequally distributed, being present in some places and absent in others, over most of the surface of this part of the bog. In the places where it was present, it often built the surface a foot or more above the water level, and growing with it were the Small and Large Cranberries, Scheuchzeria, Pitcher Plant, Mud and Few-flowered Sedges, the Slender Cotton-grass and Dulichium. The Pale Laurel, Marsh Cinquefoil, Cassandra, Andromeda, and Buckbean were present in the open places where the Sphagnum was wanting, and, where water was covering the surface, or very near it, the Horned Bladderwort and White Beaked-rush were often abundant.

An interesting object of study was afforded here by the plants which had established themselves upon a dead tree which had fallen into the water, extending from the shore, across a narrow marshy sedge-border, out about 30 feet before the end was covered by the water. Andromeda was farthest from the shore and the nearest

plant to water level, which was from 4 to 6 inches below the part of the log upon which it was growing. Sphagnum and Cassandra were nearer shore, and a fine specimen of the Pitcher Plant was next shoreward, and quite close to the shore, where the top of the log was a foot above the surface of the water were a young Yellow Birch and three thrifty specimens of young White Pine, at least 10 years old.

Back shoreward from the open Shrub Sphagnum association was a Conifer zone, the Black Spruce-Tamarack association, here not well developed, except as to shrubs, which were the same as those mentioned above. Shoreward of this, was a broad marginal ditch, with water a foot deep, and in this, Slender Sedge was growing abundantly, while between it and the Conifer zone was a good growth of Blue-Joint Grass and Alder, making a narrow and incomplete zone. On the sides of the lake where the bog was narrow or wanting, were the same shrubs as on the bog, but frequently also, patches of Slender and Prickly Sedges and the Creeping Spike-rush, growing in the shallow water. In the water in places, the peculiar little Pipe-wort was growing, but not in sufficient quantity to make it a factor in the filling of the lake.

As will be seen by comparing these bogs with others described, they present no marked peculiarities, the chief ones being the presence of the Cinnamon Fern in the first, and of the Blue Flag in the zone of advancing plants, in the second, but these are minor matters and apparently insignificant. The Blue Flag is a water seeking species, and was present, where found, quite probably as the result of disturbance of the normal conditions by man, which gave it a chance to establish itself where it now is.

North of Houghton, in a somewhat extensive bog near the entrance to the Portage Lake ship canal and on its western side, was a marginal zone of Sweet Gale, standing in the shallow water. This bog was, in places, somewhat open, with areas of sedge, but in general, was covered by the Conifer-Shrub association.

Bear Lake: Another small boggy development of peat north of Houghton, was examined at Bear Lake, a sand dune lake, at the north end of section 23, T. 56 N., R. 34 W. This was the farthest north that any study was made, and is of interest on that account. The lake was shallow, with evidences of considerable fluctuation in the water level and around much of the margin there was little organic matter, except a thin coating of algal residue mixed with the fragments of shells, and of the larger plants of the lake and its shores. On such shores the vegetation was scant and of ordinary shore plants such as Rushes, Small Spike-rush, Willows and Sedges. Above this strand-flora however, was a fairly constant zone of White Cedar, Sweet Gale, and Cassandra, a foot or more above the water level, which was probably high at the time the lake was visited, because of a very heavy rainfall a day or two before. In a slight embayment on the east side of the lake, was a small quaking-bog which was covered by the Slender Sedge and Sweet Gale on the shoreward side, the latter forming a dense fringe against the Alder zone on the shore. With the Sweet Gale was some Cassandra, Sweet Flag, Marsh Cinquefoil, and a little Sphagnum. Lakeward of the Sedge area was a zone of low plants, mostly a small slender species of Spike-rush, which covered the ground over much of the zone, but had associated with it the Horned Bladderwort, Dulichium, the Bulb-bearing Water Hemlock, Cat-tail, Yellow Pond Lily, growing in the marsh, scattered plants of Lake Bulrush, and along the edge of the water, a slender form of the Broad-leaved Arrow-head. The bottom of the lake was 6 feet below the surface of this bog. Growing in the water at some distance from the shore, were the Yellow Pond Lily, and in places, the Lake Bulrush. In this bog it was difficult to determine whether the plants now on the surface were actually building a mat out from the shore or whether the present structure was built by other plants which had been killed out and their places taken by the present association, but the structure was very weak, as if formed from very frail plants, and it was possibly the result of the growth of the rootstocks of the Spike-rush. As has been noted, the Slender Sedge was shoreward of this part of the bog and Sphagnum, the little which was present, was still nearer the shore, so that here, as elsewhere, it was playing no part in the formation of the peat, except in a very superficial way, after the surface of the deposit had been raised above the water level by the growth of other plants.

Buried Peat on the Shore of Lake Superior: In connection with the work at this point, it may be of interest to mention the occurrence of a stratum of peaty material which is exposed in the face of a recently cut bluff on the shore of Lake Superior about a half mile from Bear Lake.

A storm, a few days before, had cut into the base of the bluff and about 8 feet above the water level, on top of a mass of reddish till, was a layer of black, fine-grained, peaty material nearly a foot thick. Above this, was a stratum of gravel 2 feet thick and then wind-blown sand to the top of the bluff.

The peat was probably formed in a shallow bar-formed pond, which later was invaded by storm waves which covered it with the gravel which now overlies it; subsequent changes heaped up the sand over this and lowered the level of the water, or raised the shore, and only recently has the lake begun to cut into the deposit again. But for the gravel stratum it would be a probable assumption that the peat was formed in a shallow depression between dunes, and covered with wind-blown sand, but the gravel above the peat was too coarse to be blown about.

Lakes Near Marquette.

At Marquette two types of growing bogs were studied, those about small lakes and those which were developed between sand dunes, along the shore of Lake Superior. But two lakes were studied here, the first in

the N. E. ¼ of section 10, T. 48 N., R. 25 W., and the second on the line between sections 3 and 4 of the same township. In the first, there was a considerable marshy area on the west side, and the usual peat-forming plants more or less well distributed all around. The chief marginal plant around the greater part of the water was Sweet Gale, which also grew in crevices of the rock outcrop at one point on the lake up to a height of 4 feet above the water. In a selected area, it was found that the Yellow Pond Lily was growing in the water, and shoreward a zone of Slender Sedge, then one of Dulichium and above this was a zone of shrubs, Sweet Gale and Cassandra near the water level, and Common Alder and Mountain Holly above it. This gave each of the usual zones found in many lakes a representation, but in this one, the zonal arrangement was not uniform about the entire pond, nor about much of it, the shrub zone being the one most generally present, as noted above. Some interesting relations were noted here among which were the following: The mature part of the bog had a Conifer-Shrub society, mainly Tamarack and Common Alder; Cassandra and Sphagnum were not found in the parts of the Tamarack-Alder association examined, although Cassandra remains were abundant, suggesting the possibility that the plants had been killed by the shade of the Alders, since the species is sometimes present under pure Tamarack growth. In the same amount of shade where the Cassandra was wanting, the Labrador Tea, Low Blueberry, Wintergreen and Creeping Snowberry were abundant.

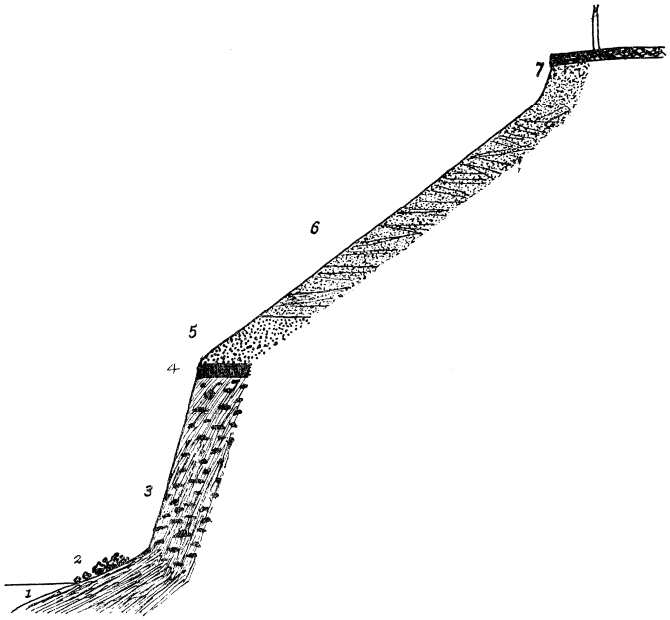

Figure 15. Section of bluff, shore of Lake Superior 2 miles east of Portage Canal, showing buried peat bed.

1. Water level.
2. Shingle beach.
3. Reddish till.
4. Peaty bed.
5. Gravel stratum.
6. Dune sand.
7. Soil layer.

The shrubs of the marginal zone, which included Cassandra, Sweet Gale, Mountain Holly, Andromeda, and Labrador Tea, all grew up on the banks of the lake, above the peat of the margin, to sand, and flourished in it, and with them grew Meadow-sweet and Jack and Norway Pines. The Labrador Tea and Cassandra, in the dryer parts of this zone, were associated with the Common Brake, the Low Blueberries, Trailing Arbutus, Wintergreen, Prairie Willow and Jack Pine.

Cassandra was also found growing in crevices in the rocks here, 3 or 4 feet above the water, with Cranberry, Huckleberry, Low and Canada Blueberries, Bearberry, Three-toothed Cinquefoil and the Sweet Gale. These dry-ground plants, higher up on the rocks, were dominant, but were about equal in numbers with the others, where the two types come together and the overlapping area formed a well marked tension zone.

The second lake was quite different in its state of development, having a sedge marsh all around the margin, varying in width in different parts, however. In the rather shallow water was a considerable amount of Yellow Pond Lily, shoreward of which was a zone of Lake Bulrush, then one of the Slender Sedge, with occasional areas of Dulichium and of Sweet Gale bushes, among which Reed-grass was of frequent occurrence; the shoreward border of the Sweet Gale here also having the tall stems of the Reed-grass frequently showing as an associate. This zone is bordered by a good growth of Jack Pine, which covers the high ground in this locality.

From these descriptions it is evident that the lakes about Marquette are again not especially different from those of other parts of the region studied, and that the same plants that have been pointed out as being active in the formation of peat, and in filling and covering lakes, are active here, and no others were especially important or significant in the processes.

Lakes and Bogs Between Newberry and Grand Marais.

The region about, and especially to the north of Newberry, was next visited, in company with Mr. Frank Leverett of the U. S. Geological Survey, in order to study conditions in a region of extensive peat deposits.

The Great Swamp: The great swampy area between Eckerman and Newberry deserved special attention and a much more extensive study than could be given it, but from what was seen, it seems probable that the swamp is formed in a very flat, poorly drained, sandy plain, with a great number of low sand ridges which may have been either wave or wind formed, and which farther check the outflow of the water and hold all the rain which falls upon them. The peat beds seem very generally shallow, a foot or two deep, although much deeper in places, and it is evident that draining, followed by drying out, would reduce the thickness to a few inches.

The greater part of this area, except where beavers built dams and flooded considerable areas, was probably originally covered by mature .swamp plant societies, with Cedar, Spruce and Tamarack as the dominant elements, before fires and lumbering produced the many changes which are apparent. At present, however, the places which have been burned over show bog and swamp societies in various stages of rejuvenation and it is possible to get some idea about the way in which plants have built up peat here. The sedges, grasses, Cat-tails, Sphagnum and shrubs all seem to play about the same part here as they do around the borders of lakes, and one sees a sedge marsh with a zone of shrubs around its border, and Sphagnum beneath the shrubs, or in another place, a broad, flat area covered with Blue-Joint Grass or Cat-tail, according as the surface is high or low above the water level, and in uncleared or unburned areas, or those less recently burned, extensive stretches of Cassandra or Cedar, Spruce and Tamarack swamps. Reading past history in the light of present developments makes it seem probable that these extensive and often shallow deposits of peat were largely formed by sedges and grasses, growing in wet or flooded soil, until the deposit grew nearly to or above the water level and then the shrubby plants and coniferous trees gradually covered the ground.

Small Lakes: In the region north of Newberry, several small lakes were visited, of which two or three will serve as examples. The first was a small kettle hole lake on section 33, T. 47 N., R. 10 W., in the morainal region, which was here covered by nearly unbroken hardwood forest. The open water had a considerable number of plants of the Yellow Pond Lily and the Water Shield forming an interrupted zone. Shoreward, around the margin, was a zone of Andromeda and Cassandra pushing out by means of their long branches into and over the water, in the manner described in detail elsewhere with Fig. 13. A short distance back from the edge of the wafer, Sphagnum and the Pitcher Plant and some other herbs were present, and with them were noted the Labrador Tea, Pale Laurel and other shrubs, and near the shore a dense growth of Spruce and Tamarack. This heath and conifer association was not studied in detail, but no important variation from usual associations were seen, except, it may be of interest here, to note the occurrence on the shoreward margin, of the Choke-berry and White-rod, which had not been found in this relation before, except in a few cases, where the Choke-berry occurred alone in a similar habitat. The Heath zone was practically unbroken around the entire border of the pond, but it was usually not more than a rod or two wide.

McLeod's Lake: 10 miles north of Newberry. This was also in the morainal region, so that it may be compared with the other. It was a larger body of water than the first and on the north side had a narrow sedge marsh. On the east side little if any sedge was visible, while in some places on the west side there were patches of Cassandra growing out on the margin of the open water. In a few places on the north side, shoreward of the sedges, were areas of Cat-tail, and some were noted also upon the western shore, where were also seen stools of Blue Flag, Sedge and Bur-reed. In the water was a quantity of a small Pondweed, the species of which was not determined. The most remarkable thing about this lake was the presence in the water to within a few inches of the surface, of a finely divided ooze, which was so soft that it could be easily penetrated by sticks to a depth of several feet, and which seemed to be of the same nature as the algal deposit already described. Here, however, the owner reported that there was a deep deposit of marl below the ooze, which latter was so soft in the deeper parts of the lake, that fish readily swam through it. But a very small part of this basin had been filled by the higher plants, and the steep high banks come down abruptly to the edge of the water in most places, with no peat terrace, and very little beach. The surrounding hills were covered with hardwood timber except where this had been cleared off.

Stuart's Lake: The most extensive bog seen about a lake in this region, was at Stuart's Lake a few miles northwest of the Half-Way House and McLeod's Lake. This was a larger basin and lake than either of the others described, and had been extensively filled at the eastern and southern sides. On the south side was a dense hardwood forest, but on the east and north sides, were steep banks which had formerly been covered with a good growth of Pine, now represented by stumps and scattering groves of trees of small White and Norway Pines. Plants of the Yellow Pond Lily and a Pondweed were abundant in the water not far from the edge of the bog on the eastern side and formed a thinly covered zone on a part of the north side as well. The advancing plant on the margin of the water was Cassandra, and the same shrub was exceedingly abundant in the hog as well. The Cassandra marsh, as one proceeded shoreward across it, first had Sphagnum and a mixture of other herbs and shrubs, then scattered, small and stunted Spruces and Tamaracks, and over quite a large area at the eastward end, larger, but still stunted White Cedar, Spruce and Tamarack, forming an open sparse growth. Below, covering the ground, was a dense growth of Sphagnum often built up in hummocks 2½ to 3 feet above the water level. In the depressions between these was an abundance of Virginia Cotton-grass, and Wool-grass, with the Sheathed and Slender Cotton-grasses scarcely less common. On the taller hummocks, the Hair-cap Moss was commonly the plant making the top stratum, while the Labrador Tea, Cassandra, Pale Laurel, Choke-berry, Mountain Holly and Cranberry, with the Three-leaved Solomon's Seal, Magellan's and Three-seeded Sedges, the King and Cinnamon Ferns, and Pitcher Plant were here associated with the conifers, the shrubs growing chiefly on the hummocks.

On the north side was a steep, sandy bank rising about 30 to 50 feet above the lake, and covered by a series of groves of Norway Pine, with dry-ground shrubs and herbs. At the foot of this slope was a narrow terrace of peat, from less than 10 to more than 20 feet wide,

bordered by a well marked ridge of the same material on the lakeward side, formed by ice-shove during the winter. This ridge was 2 or 3 feet high, and, with the bog behind it, was covered by Sphagnum, Andromeda,, Cassandra, Huckleberry, Winterberry, White-rod, Labrador Tea, Canada Blueberry, Mountain Holly, and Choke-berry forming a dense growth. The Choke-berry, Andromeda, Cassandra and Winterberry grew down over the lakeward side of this ridge and into and over the water to a depth of two feet. The peat here was a shallow, superficial coating, and in places was wanting entirely, where the sand plants came down to the water, which seemed higher than normal.

Lakes at Deer Park Life Saving Station: The largest of these is between 30 and 40 feet above Lake Superior and has sandy bottom and shores. In the water were White and Yellow Pond Lilies, two or more species of Pondweed, the Slender Naias, Bur-reed and a slender form of Arrow-head. The principal plants along the margin were Sweet Gale, and the Common Alder. In no place around this lake did there appear to be any filling by peat, nor in another smaller one lying a short distance to the west. This is in marked contrast to conditions in various lakes and swamps between Deer Park and Grand Marais, where, in the borders of some of them, were found interesting mixtures of the high ground and bog societies. In one sedge marsh (in which the Slender Sedge was dominant) with a Cassandra border, the Cassandra ran up on the bank to a height of 4 feet above the water level, into the zone of Jack Pine and grew with the Blueberries and Dwarf Sand Cherry. The Cassandra did not appear in the marsh at all, except on logs which had fallen into it, and thus furnished elevated spots on which the shrubs established themselves, clearly indicating their preference for dryer conditions than the marsh furnished.

Lakes Between Grand Marais and Newberry: In crossing the country from Grand Marais to Newberry, a number of small, as well as large lakes, were visited and briefly examined. One of the larger lakes was Island Lake; this had a sandy shore where it was not covered with plants, in places 10 to 20 feet high, but generally it was surrounded by a peat terrace from 10 to 50 feet wide, or, in places expanding into a broad marsh. In coves and indentations in the margin, there were colonies of Yellow Pond Lily, but no marked zone of this plant was seen. The marginal zone was of sedge, apparently the Slender Sedge, which had a strong admixture of Cassandra and Andromeda. In the border, between the sedge and shrub zones. Sphagnum was present and was abundant in the shoreward shrub zone which was here made up largely of Cassandra, Andromeda and Pale Laurel, with "islands" of White Pine, Black Spruce, and Tamarack. Near the shore there was an abundance of Creeping Snowberry, and Withe-rod. The herbaceous plants noticeable in the shrub zone, were the Few-seeded Sedge, Virginia Cotton-grass, and Pitcher Plant. Where the shores were high the Cassandra was often growing in from 1 to 2 feet of water. The water level seemed recently to have risen here, but the marginal plants were in no way suffering from the excess of water when the lake was visited and apparently even if the elevation of the water were permanent there would be little change in the relations of the plant zones, except that sedges might establish themselves a little more quickly among the shrubs of the present marginal zone, than they would be able to on the bare shore.

A small lake east of Island Lake had a peculiar appearance because of the shallowness of the water and very numerous small islands of plants scattered over the surface. The formation of these islands was due to a sedge, probably one of the turf forming species but this could not be positively determined, as the islands were inaccessible. On the sedge foundation were growing Andromeda, Cassandra, Pitcher Plant, and the Virginia Cotton-grass. Other plants were present but could not be identified with certainty. The marginal plant along the shores of this lake was Dulichium, growing upon the bottom in shallow water. Shoreward of this was a zone of Slender Sedge, one of Cassandra, which in turn gave place to a clearing society in places where White and Norway Pine formerly grew, or to Balsam, Hemlock and various hardwood tree species, where the soil was moist and loamy, and there had been no fires. It was difficult to understand how the small tracts of plants called "islands" above, could establish themselves in this lake, at the present stage of water, and it seemed almost certain that they had not done so, but had started in some period of low water, and had been able to hold on during the rise of the water. Such islands must serve as nuclei of dispersal for the plants growing upon them, and from them there can be little doubt that the oozy bottom of the lake will be covered much more rapidly than from the margin alone unless there should be an elevation of the water sufficient to submerge them and their plant societies entirely for a long time.

From the foregoing evidence it seems apparent that conditions in the swamps and lakes of the region between the railroad and Lake Superior in the great swamp district of the Northern Peninsula are practically identical with those in the other parts visited, and that the same plants as noted elsewhere and in practically the same relations are engaged in building up peat deposits.

More than anywhere else, perhaps, is the importance of water in the process of peat formation impressed upon one, for here, even in very sandy land, if the water level is usually at, or near, the surface, or slightly above it, a shallow layer of peat is formed, even when almost no humus at all is formed upon slight sand ridges a foot or two above the water in and around the depressions, as is very frequently the case, especially in the extensive swamp area mentioned above.

Trout Lake Bogs: While none of the lakes about Trout Lake Junction were studied, the extensive bogs lying along the railroad, northwest of the Junction, were visited. These lie in depressions between nearly parallel ridges of wind-blown sand, which are built up on a gentle

slope and each ridge acts as a sort of dam to hold the water back from running off down the slope. The peat in these depressions was shallow, said by section men on the railroad to rarely exceed 4 feet in depth, and usually to be about one foot, and, as sand was commonly exposed in the bottoms of the railroad ditches, this statement was probably correct. Many of the bogs were in the climax condition, and such were characterized by a rather dense growth of Black Spruce, as the dominant species, growing to a height of about 40 feet, and having a maximum diameter of 12 inches, but usually of from 6 to 8 inches. The best trees grew on the sides of the low sand ridges, about 3 feet above the water level in the bog. Above the spruces on the ridges, Norway Pine was the dominant species, while the Jack Pine was mixed with both the species, and in places formed dense pure stands in the bogs, entirely replacing other species of trees in such places. Under the spruces on the sand ridges, as well as on the peat, was an undergrowth of Labrador Tea, waist high, and with it Withe-rod, Cassandra, Choke-berry, Mountain Holly, Mountain Ash, Canada, Low Black and Low-bush Blueberries, and the Common Brake. Below these, were Hair-cap Moss, Trailing Arbutus, Wintergreen, Goldthread, Bunchberry, Creeping Snowberry, Clintonia and Wild Lily-of-the-Valley, with some Sphagnum in the hollows. In the lower parts of the swamps, Sphagnum is more abundant and covers the ground. In one place where a test was made, in such an association, there were only 2-4 inches of organic matter or humus above the underlying sand. In some parts of this area the Labrador Tea was found growing up the sides of the ridges, to a height of about 6 feet above the water level, associated with the Common Brake and the Blueberries, and it was very thrifty in such places, reaching a height of about 3 feet. It was generally above all the other bog plants, often forming a zone above the Cassandra and Pale Laurel on the ridges, and was not noted at all in the moister parts of the bogs, except on sand knolls; the Pale Laurel was found growing on the ridges higher up than Cassandra, although in some places the latter species was found on the railroad embankments as high as five feet above the water in the ditches.

In a series of bogs, about 4 miles from Trout Lake, the bog surface was higher on the east side of each successive ridge than on the west side, the general slope being to the west. In some of these bogs, the surface had been burned over or cleared, and in such, Cassandra often formed the dominant plant, but in others the Cat-tail occupied the ground, or grew with the shrubs between the stools. Sphagnum was sometimes present, and various Sedges and the Cotton grasses were more or less common. Not infrequently, where there had been no disturbance of relations by man, the depressions were covered by a Spruce-Tamarack or Pure Spruce association. The tops of the ridges between bogs were covered with White and Norway Pines, with Spruces growing half way up the sides.

For some distance, in a district somewhat nearer to Trout lake than that just described, the Jack Pine was the most frequent tree in the bogs, growing with the same shrubs which are commonly associated with Spruce and Tamarack in similar situations. The trees were growing rapidly and were in denser stands than Tamarack or Spruce usually develop in such situations and were from 6 to 9 inches in diameter. It seemed probable that this species had established itself in the bogs after some severe fire during a dry time, and had afterwards been able to maintain itself in competition with the slower growing swamp trees, after the water level rose again.

The Formation of Peat Near the Shores of Lake Superior.

But a single opportunity presented itself to study marshes near the shores of Lake Superior; at Marquette a series of observations were made on some marshes formed in shallow depressions formed by cutting off a portion of Lake Superior by sand bars in the vicinity of Presque Isle Park, and in the hollows between sand dunes in other places.

At the end of the electric railway to the park, near the ore docks, was quite an extensive wet sedge marsh, formed by the growth of the Slender Sedge. Upon the marsh, growing with the Sedge in a foot of water, were scattering plants of Andromeda, Myrtle-leaved Willow, Marsh Cinquefoil, Buckbean, Bulb-bearing Water Hemlock, and low growing plants of Sweet Gale. In the ditches, by the sides of the road, were the Yellow Pond Lily, a small Pondweed, a moss, probably Hypnum, and Greater Bladderwort, and extending out from the cut turf on the sides, Creeping and Mud Sedges, Myrtle-leaved Willow, Wild Calla, and Marsh Cinquefoil, the latter extending out 5 feet from the shore, and nearly half way across the ditch. The Mud and Creeping Sedges also made good growth in the water, and about their roots and stems were collected masses of algae and Bladderwort. Among the plants of the Pondweed, which were growing in a shallow place, the Slender Sedge had grown out 3 or 4 feet in one place, but was rooted in the substratum. Shoreward of the marsh was a border of Cassandra and Andromeda, which grew up on the sand in company with Norway and Jack Pine, Huckleberry, and Low Blueberries and other dry ground species, and in one case Cassandra was building sand dunes, sending out roots as the sand was piled about it by the winds, just as it does into Sphagnum which grows up around it. It was evident in this place, that there was no difference in the plants, or in the order of their appearance in the bog or of their relations to each other or the water level from what would have been found in any shallow basin and that the formation of peat was going on here just as it would have gone on in a shallow pond inland.

In a broad marsh back of sand dunes, a half miles or more west of this station, the filling had gone a step farther and the heaths were more abundant and trees had established themselves, a group of Tamaracks

being noted on one side of the marsh. The Cassandra formed a well-marked zone in places on the shoreward side; the former shore was definitely shown by a zone of Common Alders, between the bog society on one side, and the dune plants on the other. In places, the Labrador Tea, which grew within the Alder zone, was found growing up the landward side of the dunes, and associated with Huckleberry, Wintergreen, Trailing Arbutus, Bunchberry, Twin-flower and Bear-berry, the latter a very common plant upon the most exposed part of the dunes.

Formation of Peat in Sand Dune Areas Near Lake Superior at Marquette.

Along the driveway south of the park, near Picnic Rocks, a study was made of a series of shallow depressions between successive dune ridges, and while but a short time could be given to this locality, a probable succession of plants and conditions for these hollows was worked out. Immediately behind the most recent dune line was a wet, open swale with water standing in it in places. This swale was, as is usual in such localities, long and narrow, and the water was probably not over 2 feet in depth. In the water were growing the Slender Sedge, Andromeda and the Marsh Cinquefoil, and upon the shores, a well-developed marginal zone of Cassandra, and shoreward of this, a zone of Common Alder, Poplars and Tamarack, running into the dryer ground association of White Birch and the three species of Pines. Shoreward of a second broad ridge of sand was another depression, in which were pools of shallow water interrupted by slight elevations of moist sand, or sometimes of humus. Around the depressions Cassandra was usually present, and with it were some two or three species of Sedge, and often near the margin of the water or growing in the margin, the Blue Flag and Nerved Manna-grass. Here, also, were found the Myrtle-leaved Willow, the Mud Sedge, Dulichium, Meadow-sweet, Wool-grass and Marsh Cinquefoil. Shoreward of the Cassandra, in the shade of the Tamarack and Black Spruce, were the Labrador Tea and Common Alder, the latter characterizing this zone. A third hollow, landward of the third dune line, was deeper and broader than the others, and was surrounded by the Slender Sedge, shoreward of which are Heaths and Conifers. Higher and older swales were visited and in some of these were small, mature bog societies, including, in some places, Sphagnum. It was apparent here, that the Sedges and some of the Grasses were the first plants to establish themselves about the water in these swales, and that certain of the bog heaths, notably Cassandra, was almost as soon on the ground.

That these shallow depressions are not all overgrown and filled up, is most probably due to the facts that they are so shallow and of such limited area that, in periods of drought, the water entirely disappears from them and leaves only the dry sand for the plants to grow in, and in wet periods they fill with water and drown out the plants which may be growing in the bottom. During the prolonged dry times the humus which may accumulate in wet periods is partly or wholly dried up, so that it often disappears entirely. It is then only in a prolonged wet cycle that the peat can accumulate sufficiently to insure filling such depressions.

Buried Peat Near Marquette.

On the outer dune, which had been cut into by a severe storm a few days before, an interesting section was obtained. The top of the dune was from 10 to 15 feet above the present gravel beach, and its foot was perhaps 20 feet from the water when it was quiet. The storm waves had cut under the base of the dune, the sand had split off and had left a vertical face. At the base of the section was a stratum 6 to 8 inches thick, of reddish brown sand that is, sand stained and cemented by bog iron; immediately above this a stratum, a foot in thickness, of peat, or humus, filled with the unchanged roots of shrubs and of Norway Pine and in the section was the partly decayed trunk of a Pine with its roots in this soil layer. Above the peat stratum was sand for about 2 feet, then a layer of Norway Pine needles well preserved, and within a few inches above this, a layer of black iron sand, from ½ to 1 inch thick. From this to the surface there were irregular strata of sand, mixed with roots of trees, grasses and the leaves of pines. (Fig. 16.)

From this section it was evident that formerly the shore of the bay extended some distance farther out than at present, when the peat bed was being formed and that after it had reached its present thickness and trees were growing upon it, the existing dune line was established, probably as the result of cutting back the shore through a previously established dune line behind which the peat bed had been formed. The building of the dune killed the tree, and before the wood could decay it reached its present height, only to be cut into by storms during the present high stage of water in the lake. The presence of plant remains of various kinds in the sand shows that the dune was built up gradually, but that the first few feet were heaped up rapidly since in them there were no vegetable remains noticed. The bog iron below the peat bed was formed by the leaching action of the water from the soil bed, upon the iron compounds in the sand, and subsequent decomposition of the soluble organic compounds into insoluble inorganic ones. This form of action of water from marshes and forests is exceedingly common in the Northern Peninsula, where large areas of sandy soil, rich in iron, are underlain by a stratum of "hard-pan," or iron-cemented sand, at a depth of a foot or a foot and a half below the surface, which prevents rapid percolation of water, and enables the soil to support a better type of vegetation than sand usually does. This section is also an excellent one to show in a small way, how coal and iron beds may be related, and how fossils may be preserved by other means than by the action of floods, or any form of submergence by water. The stratum of black sand may be taken as an illustration of the sorting action of wind of nearly uniform

velocity. It seems as if the iron sand were blown up with the ordinary kinds by heavy winds, then a time came when, for a period, the lighter grains were moved along and the heavy iron particles left behind and thus concentrated. It is also possible that the iron and sand stratum may represent a severe storm wave action, but this is not probable, unless the present dune line had grown up at the top of a beach when the water of the lake was notably higher than it is at present, for ordinary storm waves, working at the foot of a dune line, cut the sand away and do not deposit.

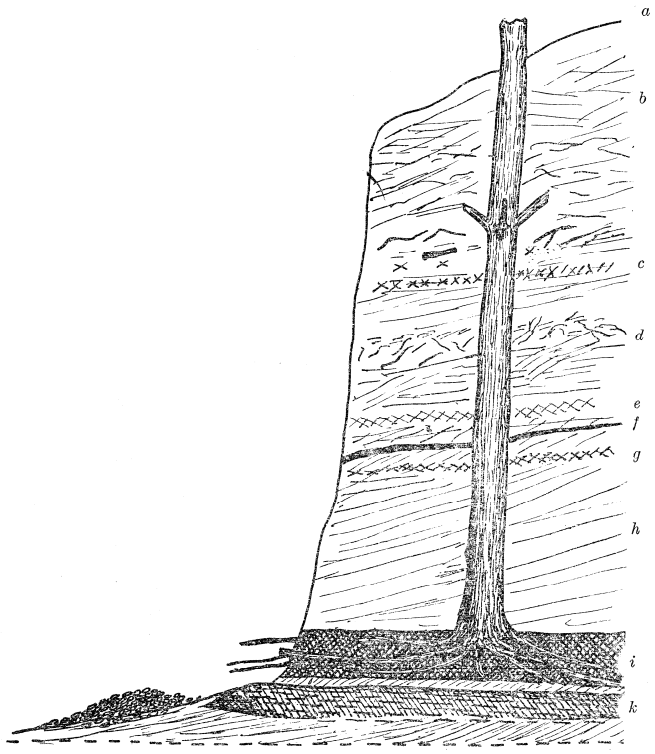

Figure 16. Buried peat bed near Marquette, with bog iron stratum below and sand dune above. Exposure made by easterly storm.

a. Stump of buried tree.
b. Sand strata with roots and other plant remains.
c. Pine needles.
d. Sand with grass remains.
e. Pine needles.
f. Iron sand.
g. Pine needles.
h. Pure sand, cross-bedded.
i. Peat stratum, with standing pine stump.
k. Bog iron.

Formation of Peat on the Shore of Lake Michigan Near Manistique.

A study similar to that made at Marquette, was made near Manistique, under more favorable conditions, for at this station there were larger areas for observation, much less disturbed by fire and clearing than were the tracts near Marquette. The area between the town and the shore of Lake Michigan, on the west side of the river, is covered by ridges of wind-blown sand from 2 to 15 feet high above the general level, and from 50 to 500 feet broad, alternating with long narrow depressions, many of which have bogs or standing water in them. The series is approximately parallel and follows the trend of the shore of the lake. The dunes on this shore were much higher and more massive than those at Marquette, because of the more exposed position and their proximity to the mouth of a large stream, carrying abundant sediments. The dune line nearest the lake is a high, massive ridge, back from the water a distance of several hundred feet, and partly covered by dune grasses and shrubs and with scattered white pines and a few other trees. In the depression behind, or shoreward of this, was found a series of shallow ponds, long and narrow, as at Marquette, but wider and deeper.

Around the open water of these were little, narrow marshes, in which were growing the following plants: Nerved Manna-grass, Wool-grass, several species of Sedges, Blue Flag, several Rushes, Small Bur-reed, and in one place Dulichium was established. Of shrubs, the Common Alder, Meadow-sweet and Sweet Gale grew nearly to the water's edge and the dry ground species from the older, shoreward dunes, extended down to within about 2 feet of the water level; these were the Hair-cap Moss, Huckleberry, the Low Blueberries, Choke-berry and the three species of Pine. It will be observed that the water-loving plants noted above are, almost without exception, those which might be found in any wet place and that most characteristic bog and peat forming plants are absent. No filling of organic matter was observed in any part of the line of pools behind this most recent dune line.

Passing over the second dime line, on which the sand was fixed by a covering of the dry ground plants mentioned above, and by the Pennsylvania Sedge and the Bunch Grasses, a second series of pools of water was found in the depression between this and the next ridge shoreward.

These water holes had evidently been dry for a part of the year, but around them the Nerved Manna-grass and Wool-grass were the dominant plants and, in some of the hollows, the ground was covered down to within about 18 inches above the water level of that date, with a dense growth of Hair-cap Moss, which formed a well-marked line at the lower limits of its growth. Below this, and extending down into the water, was a zone of Sphagnum, the plants just covering the ground, in which were growing Blue Flag, Nerved Manna-grass, two or three species of Rushes, the Lance-leaved White Violet, and Bog Club-moss. None of these plants are known to be important as humus or peat formers except Sphagnum; in connection with the latter plant, it is interesting to note that it maintains on this slope the same relation to the water level and the Hair-cap Moss, that it assumes in bogs, where the two types grow together, i. e., it was below the latter species and near the water. Its presence in the water here may be accounted for by the rise in water, due to heavy fall rains.

The society of plants described above, was apparently a temporary or pioneer society, since most of the species

are frequent on the freshly exposed banks of those lakes in which the water is receding and may appear in any moist place. The presence of Sphagnum, on the other hand, was probably significant, and through its development, the ground would probably be kept in condition for the germination of seeds of the plants of the bog societies. Several of the smaller pools in this series had the zone of Hair-cap Moss, with Sphagnum either just starting at the edge of the water, or covering the space between the water and the lower margin of that zone. Around one of the pools, the marginal plant was chiefly Wool-grass; at another the Hair-cap Moss zone was found to have Lance-leaved White Violet, Trailing Arbutus, Bog Club-moss, and a species of Panicum, and in a depression, Sphagnum 2 inches high. Below this zone were various Grasses and Sedges, and at the water's edge a zone of low Sphagnum, in which the Mud Sedge was growing, on the margin of the pool, with several species of Rushes. In the water were the Northern Water Star-wort, covering most of the bottom, and at one end a considerable colony of the small variety of the Creeping Spike-rush, growing with the common Rushes; besides these a few plants of Tall Cotton-grass, stools of Wool-grass, and what seemed to be the Floating Manna-grass, made up the list of species in the shallow water. The Sphagnum made a zone around the pond, but did not grow in the water. In this pool were Sedges capable of starling the filling, by building up peat, but they were so recently established that nothing had as yet been accomplished by them.

A much larger pool in this series and immediately adjacent to the one last described, separated from it only by a slight sand ridge a few feet wide, was in a very different stage of advancement in the development of its plant societies; Dulichium, two or more species of Sedges, the Tall Cotton-grass and Blue Flag, were growing in the water near the margin, while a small Pondweed grew in some abundance in the deeper places, and patches of an aquatic moss could be seen here and there over parts of the open water. Several Sedge islands of small size, upon which were growing Cassandra and Sphagnum and an area of Cassandra extending out 30 feet from the shore where the water was about a foot in depth, reduced the size of the pond and gave prophecy of its ultimate fate. The plants growing on the water's margin were the Blue Flag, Nerved Manna-grass, Common Alder, Winterberry, White-rod and, much more abundant than all of the others, Cassandra, which not only grew at the margin of the water, but in it, and above it 2½ feet up the bank to above the upper border of the Hair-cap Moss zone. With the Cassandra were Sphagnum, Pale Laurel and Labrador Tea.

This pool presented the nearest approach to the bog type of any in the series and was in such a stage of advancement that the end of the story of its complete filling could easily be seen; the causes of the differences seemed to be the larger size and greater depth of the basin, which enabled the water to persist in it during dry periods, and also, probably, to prevent fires from running over it and destroying such peat as was accumulated during favorable times.

The small pool next in the same line had the following conditions: The water was shallower and less in extent than in the other; growing in it were some Rushes, two species of Sedges and the Nerved Manna-grass. The aquatic Moss noted above was present in small quantities here, and there were a few Sedge islands on which the Large Cranberry was growing. There was an incomplete zone of Sphagnum at and slightly above the water's edge, and also areas of Large Cranberry, growing up on the banks to a height of 2 feet above the water level. Cassandra and other heaths formed a higher zone, and only came down to the water in a few places. The Labrador Tea was found here only about 3 feet above the level of the water in the pond. The stage of development here is evidently between that of the larger pond, with its complete shrub zone, and the smaller one, in which none of the heaths are yet present, even as islands.

Crossing over a third dune ridge and descending to the line of pools, but a single study was made. This was upon a long, deep hole, 125 or 150 feet long by 30 or 40 feet wide, in which the water was dark colored, and apparently much deeper than in any of those previously examined, especialy at one end, where the pool was scarcely 10 feet wide. The broader part of this pond was surrounded by a zone of the shrubs, Sweet Gale and Cassandra growing in the water and up to the bank and with them were the Large Cranberry, and the Mud and other Hedges as associates. Sphagnum was not noted here, although it may have been present in places, as conditions were favorable for its growth. The marginal shrub zone was thoroughly established and in places Cassandra was reaching out from the shore for a distance of 3 or more feet and, with the Sedges, formed a narrow marsh. Here, as elsewhere in the series, it was apparent that fluctuations of the water level, especially lowering it in dry seasons, had retarded peat development, but if the present conditions of moisture persisted, it seemed probable that the plants would establish themselves so thoroughly that no drought of ordinary duration would affect them.

Farther back from the shore, the hollows between dunes which were wet enough, were filled with shallow bogs, chiefly of the Cassandra and Conifer type, with abundant Sphagnum and most, if not all, of the shrubs and herbs of mature bog societies. The Conifers were chiefly small Tamaracks and Black Spruces, but not rarely the Jack Pine, and less often Norway and White Pines, were also present in these places. Three examples of these more mature bog societies may help to keep the series more clearly in mind; the first of these may be called a transition type from the early to the latest stage of development. The water of the depression had entirely disappeared before the encroachments of the plants which had built up the surface of the bog so that it was generally about a foot above the level of the water, except upon the elevations around stumps, where it was

more, and in places where the Sphagnum had not yet established itself, where it was less. As indicated, Sphagnum was present, but had not yet fully covered the surface of the bog, and the characterizing plants were Heaths and the Few-seeded Sedge. The shrubs forming the association were Cassandra and Andromeda, dominant, but both rather small, the Myrtle-leaved Willow, in depressions, the Pale Laurel, on the higher hummocks, the Dwarf Birch and Small Cranberry; on the borders of the bog and on higher places within its margin, in a sort of zone, were Choke-berry, Labrador Tea, Withe-rod, Huckleberry, and Common Brake. The herbaceous plants generally distributed over the whole surface of the bog were the Few-seeded Sedge, so plentiful that it gave a derided tone to the whole association, since, in places where Sphagnum was not yet established, it formed dense patches, and persisted also in the moss-covered areas in less quantities; the Mud Sedge, with the other, and with Sphagnum as well, Scheuchzeria, in wet parts of the Sedge associations, and Marsh Cinquefoil, commonly as an important member of the same association. Young Black Spruces and Tamaracks were frequent among the shrubs in dryer places.

In the vicinity of this bog was a small pond, which was still open, and around it was a narrow marsh, chiefly covered by the Few-seeded Sedge, but with small areas of the Slender Sedge and Dulichium, along the water's edge. This Sedge marsh was bordered, on the shoreward side, by a shrub zone, in which Cassandra was a conspicuous plant.

The climax, or mature stage in the process of filling the sand dune basins here, was well illustrated by a bog, one of the many similar areas, which was covered by the following plant association. The surface was covered by a deep growth of Sphagnum, which was quite uniform in thickness, although the water level was about a foot nearer the surface at the center of the depression than near the margin. The trees were chiefly rather stunted Black Spruces, with a few White Birches and Tamaracks. The dominant shrubs were Labrador Tea and Pale Laurel, which completely overshadowed the Cassandra, which, though present, was small in size and quantity. The Low Blueberries, Choke-berry, Mountain Holly, Withe-rod, Small Cranberry, Wintergreen and Trailing Arbutus were commonly associated with these shrubs, especially on the shoreward borders of the bog, where most of the species were making their best growth. The Sphagnum in this part of the bog had reached the limits of its upward growth above the present water level and was being invaded by Hair-cap Moss and Reindeer Lichen from the surrounding sand dunes. The Three-seeded Sedge was growing plentifully in the Sphagnum in the moister places, while the Common Brake was creeping into the margin of the bog from the dry soil at the sides. Where the water level was highest, in the middle of the bog, Labrador Tea was much smaller and less thrifty than in other places, either because of the excess of water, or because of its more recent introduction into this part.

In these three localities among the older dune lines, it would seem that the second one represents a stage of filling farther advanced than any of those found in the more recently formed depressions, and the first one of the series a much farther advanced one, where the Sedges have about completed their work, and Sphagnum is beginning its work of building up the surface. In the third, the record seems to show that the Sphagnum is about through, and that the bog will soon have a plant association upon it which will have most of the plants of a fixed dune association, but with a certain admixture of such bog plants as can endure the changed conditions. If, by settling or burning, the surface is lowered, or because of increased rainfall, the water level is raised, the changes may stop, or the cycle begin again at some one of its stages, as was shown in the first of the series of three just described, where the stumps of trees are now overgrown by Sphagnum and shrubs.

It was evident, from the conditions existing in this dune area, that the development of peat can hardly be said to begin, until some of the same plants have established themselves which have been found to be forming it on the borders of lakes and other places where water is abundant; after this, the order of development is the same as that about the lakes and in other depressions; the same species, in about the same relative numbers, maintain themselves through the cycle of development, to such a stage that upbuilding of the peat is about equal to the rise of the water level, or the lowering of the surface, through compacting by settling, drying out, or other causes, when a plant association develops which is relatively permanent and this, because of the ability to perpetuate itself in favorable times and persist in unfavorable periods, is a climax society and is well represented by the one last described.

The chief difficulty which lies in the way of the rapid development of peat deposits in the sand dune basins, is that the depressions are often very small in size and shallow, which makes them easily dried out, not only through evaporation, but also because the underlying sand permits rapid lowering of the water level through percolation and therefore they are likely to greatly vary, from season to season, in the amount of water which they hold, and this, in turn, makes it difficult for the bog plants to get established, or to persist after they are established. This probably accounts for the fact that, while even the most recently formed of the basins described, must be many years old, even many hundreds, judging by its distance above and from the shore of the lake and the size and massiveness of the dune which has been built up on its lakeward side, there is, yet little of the bottom covered by organic matter, and very few significant plants about its margin.

As dune basins, here and elsewhere, are commonly filled with water, even while the sides and bottom are relatively coarse sand and the older basins are usually at a successively higher level from those later formed, a few words regarding the sources and maintenance of the water level may not be out of place here, especially

since the formation of peat is dependent largely upon these factors.

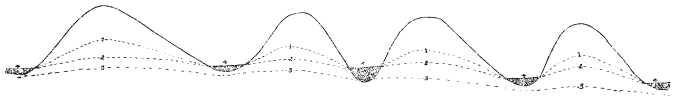

Figure 17. Diagram Illustrating maintenance of ponds on slopes covered by sand dunes in the hollows between the dunes. 1, 2 and 8 ground water level in dunes under different conditions of rainfall. 4, ponds showing the relation of surface to ground water level in the dunes. When the water level is below 2, the ponds would be shrinking, and at 3 would be dry except the deepest. The curve upwards of the surface of ground water helps to hold the pond water back, and keep it from running down the slope.

The water of the pools must all come from the rainfall, since there are no streams running into the basins among and in the dunes, but it is the rain falling upon the porous sand of the dunes themselves as well as in the area of the depression, which fills, or partly fills, the depression with water. This rarely, if ever, runs down the surface of the dunes, as it would in more compact soils, but is absorbed as fast as it falls and finds its way to the ground water level, and then laterally to the part of the depression where the water level is above the surface; that is, the pond. In Fig. 17 the relation of the water level in a series of dunes upon a sloping surface, is shown diagrammatically, as well as how the ground water itself prevents the water from the ponds running from one to the other through the sand. Actual study of the sands in dunes, shows that even in dry times the sand is moist at a distance of a few inches from the surface, and is saturated near the bottom at a varying height above the water table outside the dune. Around the depressions examined at Manistique, was a well-marked zone, extending usually about 2 feet vertically above the water in the pools, where the soil was moist, or wet, and the water level only a very short distance below the surface. This zone was occupied by Sphagnum, in several of the more recently formed basins, and in the older ones was the area in which the peat forming sedges first established themselves. The cause of greater moistness in this zone is close proximity of the water table to the surface here as it rises in a rather flat curve from the surface of the pond, to the place where the water table is highest; namely, under the crest of the done; for the water table in ridges follows the contours rather closely, especially where the soil is as homogeneous as is wind-blown sand, except that it takes a much flatter shape, the crest constantly tending to become still lower unless the rainfall is abundant and frequent.

The statement made regarding the correspondence of conditions in bogs near the shores of Lake Superior, at Marquette, with those in lake basins, holds good for those just described, but the series at Manistique was so much more complete that all of the steps in the process of filling these dune basins were more easily and satisfactorily worked out. From the evidence gathered in these places, it seems certain that no different plants are engaged in this work among the dune basins, than are doing similar work in other depressions, whether these are large or small, except that, because of the shallowness of the depressions in the duny tracts, the aquatic plants are likely to play small if any part, since the shallow water, semi-aquatic types, are able to begin their part of the work at once. In places where the sand dune lake basins are larger, the aquatic plants are often present in great abundance, even in very shallow water, but no such lakes were found in the two districts described.

Peat Bogs of the Huron Mountains.

In August, 1906, an opportunity presented itself, in connection with other work, to visit the Archean highland, which lies in Marquette county, to the northwest of the city of Marquette, known to the early writers on the geology of the region as the Huron Mountains.

This area, which covers practically the whole of the region lying north of the main line of the Duluth, South Shore and. Atlantic R. R., west of Ishpeming, as far west as the line south from the Copper Country, except a narrow border along Lake Superior, is largely made up of rock hills and rock-walled valleys, many of the latter occupied by swamps, or by small lakes. The rock is chiefly granite, with frequent dikes, by the weathering and erosion of the least resistant of which some of the principal canyon-like valleys seem to have been formed.

The general elevation of the central portion of this region is very considerable, the tops of some of the hills reaching an altitude of at least 1,950 feet above the sea, and it is probable, in a few cases, they may rise to 2,000 feet, thus reaching 1,350 to 1,400 feet above Lake Superior, 15 or 20 miles to the north. As a general thing, however, the hills are only 150 or 200 feet above the valleys, hence the general level is relatively high and the district is a plateau, or high pene-plain, rather than mountainous.

This considerable general elevation, together with the high latitude, gives to the region a distinctly more boreal climate than exists in other parts of the Northern Peninsula, already described in previous pages, snow accumulating to a depth of 7 feet during some winters and remaining on the ground from late October or early November till May, while even in August the night temperatures are invariably low and frosts are not uncommon in the valleys. As in other parts of the Northern Peninsula, there is a considerable precipitation in the form of dew and fog during the nights, so that even in rainless periods the vegetation, especially in the valleys, apparently never suffers severely from drought.

The boreal climatic conditions are clearly reflected in the vegetation, and in no part of this so evidently as in the plant associations of the bogs and of the rock outcrops. The most conspicuous and frequent forest type over much of the region is, as elsewhere in the Northern

Peninsula, the broad-leaved or hardwood type, with coniferous tree species in groups, or as isolated individuals, or in pure stands of considerable extent, in favorable places, scattered through the dominant type. The broad-leaved trees, however, over much of the area, were not of good size and made rather a light open stand, as if under unfavorable site conditions, which could not be wholly attributed to moisture and soil peculiarities, but were apparently, in part at least, produced by unfavorable temperature. The species of hardwood types which were most frequent were the Hard Maple, Yellow and Black Birches, White Elm, Red Maple, White Birch, Basswood, Hop Horn-beam, and Red Oak, about in the order named, the Hard Maple and Yellow Birch much exceeding the other species in point of numbers, however.

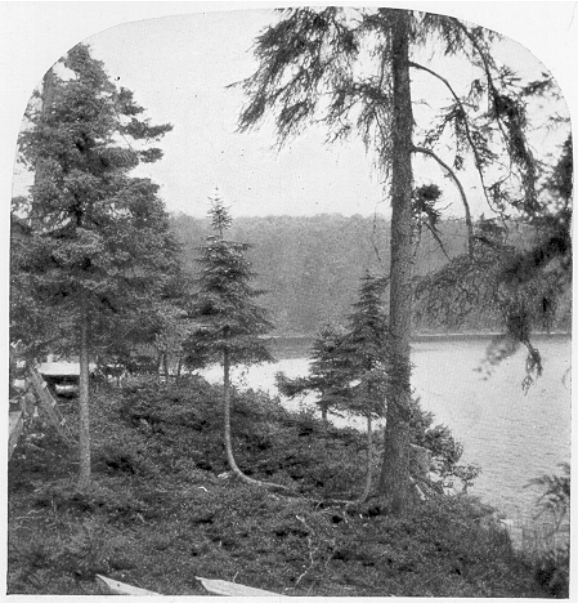

Plate XXVIII. A. Shows the end of a rock island, with peat covering, Bentley's Camp. The large tree is a Tamarack, with young Black Spruce and a Heath Society below. The hardwood forest on the shore of the lake shows in the background.

In this region, for the first time in the Northern Peninsula, the Black Spruce was found as a common constituent of the Jack Pine forest on the sand barrens, and this species also occurred rather frequently as the dominant member of the plant societies growing on exposed rocky hills. In such places, the species reached a better development than in the swamps, growing into a tall, slender, cylindrical spire, 50 or 60 feet in height, the crown only 6 or 8 feet in diameter and the trunk attaining a diameter of 6 or 8 inches, or, rarely, even a foot. This slender columnar form of crown is unusual in the forests of the eastern part of the county, and is only approached by old Balsams; the type is well shown in some of the trees in Plate XXVIII B.

In the sand plain areas this tree and the more vigorous White Spruce, grow less tall and are, therefore, less conspicuous, especially as they are here associated with the Jack Pine growing into a similar tall, narrowly conical crown, which, taken with its short leaves and persistent pendulous branches makes it resemble the Spruces and probably accounts for its common name in this region, where it is called Spruce Pine.

Plate XXVIII. B. Shows the top of the island, with old Black Spruces and a Heath Society below. Photographs by C. Bentley.

The lower lying parts of the granite uplift, those which lie below 1,800 feet above sea level, have considerable deposits of glacial till which lie chiefly on the north and east sides of the ranges of hills, the tops and south and west sides of which are bare, often precipitous, cliffs, so that in looking over the country from an elevation a very different impression of its character is obtained, if one looks toward the north, from that received by looking south. If, for example, one looks at the north-facing sides of the hills, in the vicinity of the Huron Mountain Club, T, 51 N., R. 28 W., the forest-clad slopes are covered by notably fine growths of hardwood timber, here strongly mixed with Hemlock. Near the tops of the slopes, in many cases, the hardwood growth suddenly gives place to White Pine, and when the cause of this change is sought, it is found that the Pines are growing in places where the rock is at, or very near the surface. Climbing some one of the mountains back from the shore of Lake Superior in this same neighborhood and looking northward, or viewing the south-facing slopes from one of the lakes which lie nestling among these hills, and a very different scene presents itself. These hillsides, instead of being rather gentle, long and densely tree-clothed, are steep, often precipitous, bare rock with a sparse covering of White and Norway Pines, so that it could easily be imagined that one was in an entirely different region from the first. The same general conditions prevail in going inland from the Lake Superior shores, except that the Hemlock is a less frequent constituent in the hardwood forest after a few miles, and the amount of rock exposure increases in the more elevated parts of the highland, where, formerly, nearly all

the hills had White Pine covering their tops, and in the most elevated parts of the plateau, their rocky sides as well. It may be noted, in passing, that the same differences in character of the north and .south sides of the hills may be seen in the vicinity of Marquette, near Eagle Mills.

Types of Swamps and Bogs.

As in other portions of the Northern Peninsula, the valleys of the plateau region are covered by swamps or occupied by lakes and bogs, and here also quite extensive swamps occur on portions of the sand plains which lie between the great morainal deposits banked around the higher portions of the plateau.

These swamps of the sand plains are often densely covered with a growth of White Cedar mixed with Tamarack and Black Spruce, or in places by nearly pure stands of Spruce and Tamarack, the former so dense that little lower vegetation occurs with the taller species except in openings, where various shrubs and herbs find conditions favorable for growth.

In such a swamp, on Sec, 7, T. 50 N., R. 29 W., the following species were noted: Black Spruce, quite dense. Tamarack and Balsam Fir occasional. In more open spots among the trees, the Canada and Low Blueberries, Labrador Tea, Red Maple, White Birch and a few young White Pines. Sphagnum was found, but only in spots, and there thin and making poor growth. Cassandra occurred around the borders of wet openings in the swamp. The peat in this swamp was reddish brown .and poorly decomposed, and was not tested as to depth.

Similar swamps were found along the courses of the glacial drainage valleys which cross portions of the highland, but they presented no special features, except that sometimes a swamp flora was found growing on exceedingly stony areas and even upon coarse gravels, upon which very little peat had collected, although the ground was quite full of water. The plants noted in such places were the usual swamp trees and shrubs. Some of the more accessible areas of swamps in a glacial drainage valley were seen along the Peshekeme river, near its source, along the grade of the Huron Bay R. R.

A number of lakes were visited in the divide region in T. 49 N., R. 29 and 30 W. These were usually found to have high gravelly or rocky banks, with very little swamp or bog about their margins, except in limited areas and in narrow strips. Generally these lakes are quite deep, with very little visible aquatic vegetation in them, and the water was rather dark colored, sometimes exceptionally so.

In Bulldog Lake, and another small lake connected with it, the bottom was quite soft, very near the surface in many places, and was made up for a depth of several feet of an oozy, very soft peat, which, in color and structure, closely resembled the algal peat described if it was not identical with it. These lakes lie in a long, narrow valley with generally steep rock walls, at the outlet end of which was a morainal dam. Apparently at one time there had been but a single long lake, but gradually the middle portion of the valley had become filled until only a narrow water way, or sluggish stream now connects the end portions, and even this connection has been artificially increased in width and depth through the encroaching swamp. The part of this swamp lying along the stream was rather open, with Tamaracks as the chief tree species, under which was a dense growth of shrubs, chiefly Sweet Gale, Cassandra, Common Alder and Swamp Wild Rose. The Slender Sedge, Wild Calla, Marsh Cinquefoil, Pitcher Plant and other common swamp and bog species were also noted in this area associated with the shrubs along the stream. At the south end of a small lake, in T. 50 N., R. 30 W., was a narrow but quite long bog in which White Cedar, Black Spruce and Tamarack formed the tree association, while Labrador Tea, Cassandra, Andromeda and Sweet Gale grew in dense Sphagnum below. This bog was covering what was formerly a portion of the lake but was apparently making very slow advances over the surface, as the marginal fringe of shrubs was compactly bound together by mosses and other plants and was not making the growth out into the water noted in other similar localities at lower altitudes. On the whole the lakes visited in this region were notable for the small amount of bog about them and for the absence of visible water plants, while the microscopic algae were apparently very abundant.

An important agency in the formation of swamps in this region were those industrious little animals, the beaver, which, in this unsettled area, have become again quite numerous since protected by the game laws. Their dams were frequently seen and the very considerable areas flooded by them made travel across the stream and swampy valleys difficult; in these ponds where the dam was of recent construction, as many of them were, the dead and dying trees and shrubs could be seen standing forlornly in the shallow water.

Not only were these present ponds noted, but the filled ones or beaver meadows were not uncommon, often of considerable extent, and in various stages of advancement toward the mature tree covered swamp. In these it was usually easy to discover the long, low dam at the down stream end of the tract, often covered by shrubs, while the rest of the meadow was still clothed with grasses or sedges. In one such beaver meadow, in Sec. 2, T. 49 N., R. 30 W., around the margin, was a zone of Black Spruce and Tamarack, evidently of old growth. Bordering this on the streamward side was a well-marked zone of Blue-Joint grass, growing 3 feet high in places, and this gave place to a broad Shrub-Sphagnum zone, in which there were a few young specimens of Tamarack and Black Spruce. The dominant shrub in this area was the Sweet Gale, with which was associated Cassandra, occasional plants of Andromeda, some species of Amelanchier, or June-berry, a form of the Tall Blackberry, and more numerous

specimens of Canada and Low Blueberries, and the Small Cranberry.

The following herbaceous species were noted in this zone: Pitcher Plant, Few-Seeded and Long Sedges, Marsh St. John's-wort, Canada St, John's-wort, Alpine and Virginia Cotton Grass, White Beaked Rush. Closed Gentian, Bugle-weed and Sphagnum, which covered the ground throughout this zone, and the next. Towards the center of the meadow the shrubs were first lower, then practically wanting, giving place to an Herb-Sphagnum association, with the Long Sedge and the White-Beaked Rush the most frequent species, but growing with them were Smooth Golden Rod, larger Blue Flag, Blue Joint Grass, Pitcher Plant. Round Leaved Sundew, Rough Hair-grass, and Small Cranberry.

In the outer border of this zone there were numerous young Tamaracks and shrubs; the latter in the form of small young plants, were also abundant in the Herb-Sphagnum areas, which apparently had been heavily seeded with Sweet Gale, Cassandra and Andromeda not long before.

The dam behind which this meadow had been formed was marked by a well-defined ridge, 2 feet above the bog level, on which was growing dense, very vigorous Sweet Gale, nearly 4 feet in height.

The associations found here were evidently not characteristically different from those found in open bogs in other places, and on comparison, it will be seen that the reclamation of a beaver pond into bog, marsh and swamp goes on as does the filling of any body of water, in a definite and orderly manner.

The most interesting observations made in this region of granite hills were those made upon peat-covered rock outcrops on the hills and upon a small rock island, the top of which was at least 30 feet above the level of the water of the lake in which it was situated.

The number of observations upon this type was not large, but enough of these elevated peat deposits were seen to show that the climbing type of bog, not seen elsewhere in the studies upon which this paper were based, does exist in these cooler, more elevated portions of the Northern Peninsula, especially in the valleys, where almost nightly, during the growing season, fogs occur.

The most interesting of these peculiar bogs was a high, steep, isolated rock hill standing alone in the valley of the Peshekeme river, in T. 39 N., R. 31 W., close to the stream, upon the sides and tops of which was a good growth of Black Spruce, Tamarack and White Cedar and some White Pine, Balsam-fir, White Birch and Mountain Ash, under which were the shrubs Cassandra, Labrador Tea, Sweet Gale, Canada Blueberry and a few others. In spots, on the sides of the rock, could be seen Sphagnum, evidently thrifty and making a good growth, but the larger part of the surface, where it was not too steep for any vegetation to maintain itself, was covered by a heavy growth of Reindeer Lichen, both in the open and under the trees and shrubs. The top of this rock hill was at least 50 feet above the water of the river, which bathed its eastern flanks. The peaty covering of the rock was thin, fibrous, and with very little moisture present.

A small island (Plate XXVIII A and B), was the second of these elevated peat deposits examined and was more carefully studied than that mentioned above. The rock on which this deposit was formed was small, possibly three acres, or a little more in area, had a rounded and somewhat glaciated surface, and rose about 30 feet above the surface of the lake.

The peaty covering was usually thin, a foot or less in thickness, but, in places, was said to be at least 3 feet deep. It was made up of coarse-textured, spongy, partly decomposed, brown peat, which contained the remains of tree trunks not thoroughly rotted, and quantities of the partly decayed roots and steins of shrubs. In early August, when visited, the peat was so dry as to take fire readily and was easily blown by the wind from the openings in the ground cover.

The island had been occupied as a lumber camp some years ago and all of the large Pines had been removed from it at that time, as well as other timber trees which could be used in the various operations connected with the lumbering of Pine. Later the island had been still farther cleared and occupied as a summer camp, but, in general, the natural plant covering, except the trees, had not been seriously disturbed, save where paths had been laid out and houses built. The removal of the trees, by increasing the light, had undoubtedly increased the number of individuals of some of the lower growing plants, and decreased that of others, while with the advent of man, a few weeds and cultivated grasses had been brought in, in packing material and in other ways, from the outside world, but it was still possible to determine, satisfactorily, the original relations of the plant societies found.

Including the species growing in shallow water around the island, there were four fairly distinct plant societies present corresponding to variations in habitat. These were the aquatic, the marsh, the exposed rock, or crevice, and the Conifer-Heath society. The latter covered the greater portion of the island from a short distance above the water level, with the exception of steep and exposed rock faces at various points, and was, by far, the most important and characteristic association growing here, all the others being limited in the number of species and of individuals, and in the area which they occupied, in comparison with this.

In the aquatic society of the shallow water, the following species were noted, all sparingly represented and by very few individuals: Yellow Pond Lily, Floating Manna-grass, Swamp Horsetail, Quillwort, Floating Bur-reed and Water Lobelia. Growing in the water were other species, but these belonged properly with the next society, and are given in the following list of species making up the Marsh society at this station.

Sweet Gale (the plants growing in the water were smaller and of a lighter green color than those in the Conifer-Heath society), Cassandra, Spike-rush, Creeping Spike-rush, Dulichium, Slender Sedge (in a few small areas), Long Sedge, Wool-grass, Marsh St. John's-wort, Bugle-weed, Dwarf and Canadian St. John's-wort, Small Bedstraw, Yellow Water-cress and Sweet White Violet. This society was only present in spots and narrow marginal areas of mineral or vegetable débris along the small undulations of the shore of the island, or those parts most protected from winds and waves, and, like the first society, was usually sparsely represented.

The rock or crevice society was made up of the following species, together with shrubs belonging properly to the Conifer-Heath society, present as stragglers: Low Juniper, a few plants on an open, exposed rock mass. Choke Cherry, Red Raspberry, Common Polypody, Small St. John's-wort, American Wood Strawberry, Pale Corydalis, Dog Violet, Wild Oat-grass, and Wire-grass, Mosses and Lichens.

The habitat of this group of plants was chiefly crevices and narrow shelves on the more exposed rock faces, but as there was frequently only an inch-thick covering of the peaty soil where the Conifer-Heath plants were present to the exclusion of those of the crevice society, thinness of the soil was apparently not the factor controlling the distribution of these plants, but from the situation in which they grew, it seemed probable that exposure to full light and heat of the sun, sudden and violent changes of temperature, and drought were all factors in eliminating other possible species from the places where these plants grew, and the latter factor, probably combined with rain-wash and wind effects, had prevented the accumulation of peat where these plants were found. The Conifer-Heath society covered the larger part of the island, from the Marsh society with which it merged in some places, to the very top, wherever the rock surface was not too steep to permit the peat to form. The mature trees were all of coniferous species, although a few specimens of broad-leaved types had recently established themselves in the more open places. The trees present or represented by the stumps of recently cut individuals, were Black Spruce, dominant in point of numbers, and tallest of the trees now left, Tamarack, Arbor Vitæ, Balsam, chiefly small, White Pine, represented by some medium-sized stumps, by young individuals and a few larger ones, and Norway Pine in places where the soil was very thin and dry. The Spruce, Arbor Vitæ, and Balsam were all thrifty and making as good growth as similar aged individuals in the swamps and swamp margins in the same region Where the soil was very thin the young trees were somewhat stunted.

The broad-leaved species of trees noted in young stages were White Birch, Red Maple, Wild Red Cherry, American Mountain Ash and Common Aspen. Beneath the trees there had formerly been apparently a dense growth of low shrubs, chiefly of the Heath family, and even now, the ground was completely covered by these plants, except where clearing or other artificial treatment had broken the cover. There was little zonation apparent, but the Blueberries seemed rather more abundant near the top of the slopes, and Sweet Gale and Cassandra near the water, although even near the foot of the sharper inclines, there were strong admixtures of all species.

The shrubs belonging to this society were the following: Canada, Low, and Low Black Blueberries, Labrador Tea, Cassandra, Creeping Snowberry, Trailing Arbutus, Wintergreen, Fetid Currant, Bristly Sarsaparilla, Choke Cherry, Choke Berry, June Berry, Red-berried Elder, Winterberry, Mountain Holly, Common Alder and Sweet Gale. Of these the Blueberries, Cassandra, Labrador Tea and Sweet Gale were the dominant species, the Cassandra and Sweet Gale occurring abundantly to 20 feet above the water, and Labrador Tea to the very top of the island. The other species occurred scattered over the island, some, like the Fetid Currant, Creeping Snowberry and Mountain Holly, which are commonly considered bog plants were found only on the higher parts of this island, while others were apparently accidentally present in insignificant places. In examining this list, the probability of the agency of birds in transporting seeds of most of these shrubs to the island is evident, 13 out of 18 species here having attractive and edible fruits, many of which birds are known to eat, and upon which several species were feeding during the writer's visit to this locality.

The following herbaceous species were rather sparsely present, associated with the shrubs: Spinulose Fern, Common Brake, Three-Seeded Sedge, Little Prickly Sedge, Hair-grass, Wild Oat-grass, Clintonia, Wild Lily-of-the-Valley, Indian Pipe, Wild Strawberry, Purple-leaved Willow-herb, Fire-weed, Slender Rush, Pearly Everlasting, Winged Cudweed, Sphagnum, Hypnum and other mosses and Reindeer Lichen. The Sphagnum was abundant in flat places to a height of 18 or 20 feet above the water level, while Hypnum and the Reindeer Lichen covered the ground in the dryer places. A few small areas of otherwise bare rock, on the north side of the island, were covered by a mat of Sphagnum and other mosses, and lichens, and in these it seems probable that we have an indication of the way in which the beginnings of the peat covering of the island were made, as when once the moss and lichen stratum is established, other plants soon obtain foothold and from that time on, the formation of peat may go on continuously where moisture conditions are favorable. It may be noted here that small areas of some species of Sphagnum were seen on exposed rock outcrops in several places in this vicinity, usually on northern slopes, but elsewhere in the region, they were not noted.

The remaining plants found in this interesting habitat were apparently recent introductions into the native association and included the following species: Rough Cinquefoil, Red Clover, White Clover, Mouse-ear Chickweed, Black Bindweed, Sheep Sorrel, Red Top

and June Grass, most, if not all, species which have been introduced with hay or packing material and only found in the clearings about the houses.

In considering the relationship of this type of habitat to others described, it is evident, upon comparison, that it is closely allied by the make up of its chief plant association to mature peat bogs of the wet type. Yet, in this place, as has already been pointed out, below the peat was an outcrop of crystalline rock, with relatively smooth glaciated and rounded surface, sloping on all sides of the water, and with no contact between the present water surface and the peat covering. The only source of water for this habitat, then, is meteoric water, precipitated as rain, snow, fog and dew, so that at times it must become very dry. In fact, as noted above, the peat, at the time of the writer's visit, in early August, was in an approximately air-dry condition; that is, with not more than 50 per cent of included moisture; so that it burned readily, and contained a minimum supply of water which was available for plants. As no rain fell in this region for some weeks after this, the peat must have become still dryer before the leaf fall of the broad-leaved species in October. This condition, which must have been constantly recurring during the time required for the accumulation of the three feet of peat found here, made the habitat, so far as the soil was concerned, an extremely xerophytic one, which could only be occupied by plants which are protected against loss of water by various peculiarities of structure, which have been pointed out in Part I of this report, and which most of the species found growing here possess to a marked degree. The chief question which arose in the mind of the writer, was how any association of plants could grow where there was so little water available, as some of the species had, where they were growing in rather coarse peat, only an inch or two deep, with only the smooth rock below, when for weeks there had been no rain.

In considering this and the related problem of the accumulation of peat in such a situation, it is probable that the location of such deposits in narrow valleys, having considerable elevation above the sea is significant, both in its relation to peat formation in such places as have been described, and to the plant species forming the covering from which the deposits are built up. In such valleys, during the day the air is warm and becomes well filled with moisture from the vegetation and soil, but at night the air is always cool, whatever the temperature may be during the day, because the cool air from the surrounding hills flows into them as soon as the sun sets, precipitating the moisture as dew and fog, and it is no uncommon thing in the large valleys containing lakes to see a small cloud of fog in the early part of the evening at the mouth of each tributary valley, while later, these small clouds spread and cover the whole valley bottom with a blanket of fog. The fog thus formed condenses still more visibly as dew upon the cool surfaces of the branches, stems and leaves of the plants, and may drop to the ground and be added to the ground water, or simply be dissipated in the morning, in which case it still aids the plants by saturating the air about them and in this way enabling them to conserve the supplies which they already have by decreasing the loss of water from their tissues by transpiration. This form of precipitation also undoubtedly helps to keep the soil moist in at least two ways besides that mentioned, first by preventing evaporation into the air, during at least the early part of the day and the whole of the night, and, second, by direct absorption by the upper layers of the peat so that the water of the lower parts is not so quickly drawn off by capillarity and evaporation as it would be in times of long drought. Another interesting and probably important factor in the early history of such deposits, is the condensation of moisture from the air, directly upon the bare surface of rocks, especially during changes from cool to warm weather, where the air is suddenly warmed up before the rocks and soils reach the air temperature. At such times the rocks will become quite wet, the moisture forming visible drops, especially in places not exposed to the direct rays of the sun, and the vegetation upon them will become as green as during a gentle rain. Such precipitation favors the growth of Lichens and Mosses and other pioneer vegetation and undoubtedly also prevents the early layers of vegetable débris formed, from becoming so dry that they would be destroyed by disintegration.

Precipitation in these forms, together with the generally low temperatures of the air during the growing season, which prevents excessive transpiration from the vegetation, and evaporation from the soil, are important if not controlling factors in the development of peat deposits like that described, and in the maintenance of plant societies upon them. That is, the climatic feature which makes the accumulation of peat on elevated rock surfaces in this region a possibility, is the high relative humidity of the air which here is greater than in other parts of the state with equal rainfall, because the temperature averages lower, since here, the elevation above sea level, is greater than in other places of the state of the same latitude. That this same factor of the climate should be taken into account in considering the agricultural possibilities of the soils, in this and adjacent regions, is obvious, because in such a moist climate the poorer types of soil will produce better crops than the same types would in a region of even greater rainfall, where the atmosphere was less moist during the summer season.

The general tendency of all low ground having sluggish drainage to become covered by peat and peat-forming plants throughout the region under consideration is attributable in part, at least, to the same cause.

In this connection, also, it may be well to point out that the close correspondence of the plant society of the elevated dry peat bed described above, with that of the older and more mature parts of those peat bogs having a wet substratum is of the nature of confirmatory evidence that these are true xerophytic habitats.

General Conclusions Regarding Peat Formation in the Northern Peninsula of Michigan.

From the foregoing descriptions of mature bogs in various types of localities, over a very considerable extent of the part of the state covered by this paper and of many classes of depressions in the process of being filled by the development of peat, it seems evident that, in general, the formation of peat goes on there, much as it does in the Southern Peninsula, but with some very interesting and important variations as to detail, the causes of which are not yet clear.

Comparison of Southern and Northern Lakes in the Process of Filling: The normal, and usual, boggy lake of the Southern Peninsula, which is being filled with plant débris, has more definitely marked zones of vegetation, and these are more fully developed and have more species of plants below the water level than the corresponding type in the Northern Peninsula. The zones of aquatic plants represented/ more or less fully, in a large number of lakes and ponds in the Southern Peninsula, are the Chara zone in deep water, the Pond weed zone, the Pond Lily zone, the Bulrush zone, and the Sedge and Cat-tail zone, which is the highest aquatic zone. In the Northern Peninsula the Chara zone was not seen in a single basin, but no careful examination was made to determine its presence or absence. The Pondweeds were as frequently absent as present, and when present, were usually, though not invariably, sparse-growing and small species, in thin, or broken, zones, or as scattered plants. The Pond Lily zone was also usually poorly developed, or represented by scattered plants, or wanting, and while this is true of many ponds and lakes in the Southern Peninsula, it is not by any means so generally true. The Bulrush was also more often than not found in the shallow water of the lakes of the region studied and a very striking and important aquatic plant zone is thus eliminated from the lakes of the region. The sedge zone, then, is the one which must be considered as being the most frequently present of the aquatic, or semi-aquatic zones, but as has been pointed out, in examining the series of bogs from the southern to the northern part of the western end of the Northern Peninsula, an interesting and important variant from the type of bog which has a zone of sedges, especially the Slender Sedge, as the marginal zone, was found in those in which the shrubs, Cassandra, Andromeda, and, more rarely, Sweet Gale, were the species which were growing upon and within the water's edge, and were the plants building out from the shores and covering the open water, and apparently filling it as well. As the type was much more frequent in the northern than in the southern parts of the region traversed, it seems a fair inference that in the cooler, more humid climate of the north, the shrubs mentioned are able to grow better in the water than they can in the south. Since they can endure the conditions in the water at the margin of the mat upon which they grow, their long, rigid, stolon-like branches, which seem able to live for some years, if necessary, without rooting, are much more efficient in making advance into the open water than the comparatively weak stolons of the sedges, which, to hold themselves upright and bring their leaves above the water, must have some root attachment or grow very close together in short lengths.

It is but fair to state here, that Mr. C. C. Adams reports that on Isle Royale the bogs which were examined there, all had well-developed Sedge zones, and the hypothesis that climatic conditions are the factors efficient in producing the marginal shrub zone, may have to be abandoned as untenable, but at present no other is suggested.

Important Types of Filling: The relative absence of the larger and more highly organized seed-bearing aquatic type of vegetation from the lakes of the Northern Peninsula makes it possible for the minuter and simpler kinds to form accumulations of considerable size, and as the result of their development, a type of peat hitherto unrecognized (in this country at least) must be added to those which were known before, namely algal peat, formed almost entirely of the remains of one-celled or few-celled plants. This type has already been described on page 209 and its interesting and important bearing from the geological point of view suggested, but it may be added that the Algae probably play a more important part than has been suspected in the formation of deposits of peat in the southern lakes, where the more conspicuous remains of the tissue-forming aquatic plants, mask the minute particles of vegetable matter into which the cellular types break down. While algal filling of basins of considerable size, must be a very slow process compared with that done by the higher plants, even though the work of the latter is confined to marginal terraces which are built up by their growth. If a deposit of one twenty-fifth of an inch per year were assumed for the Aigæ, it would take only 3,000 years to build a bed ten feet thick, which geologically, and relative to the time occupied in other changes upon the earth, is a very brief time, and well within the period since the basins in the drift were abandoned by the ice of the continental ice sheet. It may even be probable that the rate of building was slower than that assumed, but very much less rates may be postulated and still not be unreasonable, and out of accord with conservative estimates of the time which has passed since the last glacier disappeared from the region under consideration.

In summing up the variations in the manner in which the deeper basins are filled with peat in this region, the type in which the Swamp Loose-strife is the marginal plant may not be omitted, for while this plant was present in but a single lake among those visited, the hundreds which were not visited, may include many with this kind of marginal zone. It is not unlikely from the known distribution of the Swamp Loose-strife, that it is rare in the Northern Peninsula but it probably exists in more than a single locality, and where found is remarkably

efficient in producing a strong and enduring mat over the surface of the water.

Minor modifications in the types of marginal turf formation, especially in those cases where the sedges are present, are of some importance in determining the succession of plants after the advance has been made, and the consequent upbuilding of the surface so that trees are able to establish themselves.

The important sedges of the turf building type of the marginal zone are (1) the Slender Sedge, (2) the Bottle Sedge, (5) the Tussock Sedge, (4) the Creeping Sedge, (5) the Mud Sedge and (6) the Few-seeded Sedge. Other grass-like turf-forming plants growing on the marginal zone, which occasionally are of importance are Cat-tail, Dulichium and some of the Spike-rushes, but so far as observed, these are infrequent, except in limited areas and never were found to cover the entire margin of larger ponds.

Of the sedges, the Slender Sedge is the one most efficient and frequent as a marginal species, as was the case in the Southern Peninsula, and the slow building up of the surface of the turf made by this species by its own remains and those of other plants, has been made clear, especially where it has frequently been noted as forming wide zones almost free from other species.

Factors Controlling the Width of the Sedge Mat: The width of the sedge mat, manifestly must depend upon two factors, at least: (1) the rate at which it pushes out from the margin and (2) the rate at which the surface is built up above the water level so that the species can establish themselves and crowd out the Sedge. The fact that the Slender Sedge mat is usually wade, shows that the species does build out from the shore much faster than the surface is built up. Late in the history of its development, the mat is invaded, along the shoreward margin, by shrubs or Sphagnum, or both, after which the elevation of that part of the surface is rapid.

Periodicity of the Growth of the Mat: As has been mentioned elsewhere in this paper, there are indications, very generally found, throughout the Northern Peninsula, that all the plants have periods when they advance rapidly from the shore, and other periods when the advance is checked and all the species remain where they are established, or even, in many cases, disappear, or retreat to the shore again. The most generally operative and effective cause capable of producing such results would be changes in water level, and the advances from the shore of all the species from the marginal types, to the trees, these remaining longest on the shore, seem to be coincident with the periods of lessened rainfall and low water level. In such periods the Slender Sedge marsh may be covered for many yards of its width by shrubs and Sphagnum. While the trees appear in the older parts of the shrub zone at about the same time, and the Sedge grows outward over the marginal terrace developed by various causes beyond its edge.

In wet periods, on the other hand, all the zones, except possibly the sedge zone, simply thicken up by increasing the numbers of individuals in favorable places, and make little, if any progress in other ways; or, if the rise in the water is too great, or sudden, may be set back to some higher level by being drowned out from the lower ones. Only by such changes of water level does it seem possible to account for some apparent anomalies in the intermixture of zonal plants which were frequently noted in bogs of the Northern Peninsula, where the level of the water, when observed, was too high to permit plants growing in it to establish themselves, and some of their associates were evidently of recent introduction and were properly in the habitat where they were found.

During the longer or shorter times when the zones are not making any advance, a thickening of the turf may occur, apparently because of the increase of weight upon it as the shrub and tree associations became more highly developed. This causes a slow sinking, while the surface is built up. The sinking apparently only continues until equilibrium is established and then ceases. When a new advance of the series of zones takes place, the old portion of the mat is much thicker and firmer than the new part and the line of union between the two can usually be determined not only because the plants growing in the newer part are different, and form a simpler association, but also because the newer part is less firm and much more easily shaken, on account of its greater thinness. Sometimes the tree growth is confined to the old part of the mat and sometimes the shrubs and Sphagnum mark its limits.

If the Tussock Sedge is the marginal and advancing plant, the habit which the plant has, of building its stools up above the water level, makes the conditions very different where it occurs, from those where the sedges which make a horizontal growth are marginal. The Tussock Sedge stools, as soon as they are built up a foot, or less, above the water, become the habitat of a number of plants from the Shrub-Sphagnum zone, and these soon bind the separate stools together and form a compact turf from which the Sedge itself is eliminated, so that the marginal zone here is often very narrow, and because of the height of the surface above the water level, the zone of pure shrubs encroaches upon the favorable site to be followed by the trees, almost as soon as the shrubs are established upon it, and the Sedge, the founder of the substratum, is confined to the narrow zone next the open water. The Bottle Sedge, rather a frequent marginal advancing plant, in the Northern Peninsula, is taller and larger than any of the other marginal sedges, having coarse thick, leaves and stems and it seems to build up the surface rather faster than the other species where it is found; hence marginal zones of this plant are narrow in proportion when compared with those in which the Slender Sedge is dominant. The Creeping and Mud Sedges are slender types and are usually capable of making a turf only in connection with other species, but occasionally they form narrow marginal zones and reach out into the

water, where other plants follow upon them, but so far as observed, these two species never make extensive marginal mats themselves.

The Few-seeded Sedge is so like the Slender Sedge in its vegetative characters, that it is often impossible to distinguish one from the other, unless in fruit. The Few-seeded Sedge is frequent in low places in the Sphagnum-Shrub zone of bogs, and in a few cases in the more northern bogs visited, bore to that zone, the relation of a marginal plant, as if it had formed the mat upon which the other plants had established themselves. In a few cases also, it was observed in the marginal zone about open water, and there may have been others, where leaves alone were found, where this species was confused with the Slender Sedge, so it is given place here as a turf bearing species.

The manner in which shrubs form marginal zones around lakes and extend the structure of the bog, has already been described in detail elsewhere, page 33. It needs only to be pointed out here, that the purely marginal zone of shrubs is very narrow since, because of the height to which these plants grow above the water, the rigidity and strength of their stems and branches and their perennial habit of growth, other shrubs, sedges and other herbs, Sphagnum and even trees can occupy the structure almost as soon as it is established.

This statement regarding the narrowness of the purely marginal zone, applies equally well to that occupied by the Swamp Loose-strife, since it is also able to build up over the water level and form a substratum upon which most other plants of the bog type of habitat may grow.

It is evident from these considerations, that when most of these marginal species have created a habitat for themselves and have grown in it for a time, they develop by their growth, conditions which so improve the habitat that it becomes available for other species which promptly possess themselves of it, and overwhelm the makers, only to continue the process of improvement and be dispossessed in turn by other types.

This would proceed in a regular order through a definite series of changes to an end type of plant association, which would be able to hold the improved site, or habitat, against all comers, if climatic and all other conditions were absolutely uniform, so that there would be no marked fluctuations in water level, in evaporation, and in the various other important factors, which materially affect the kinds of habitat under discussion. But as has been pointed out frequently in previous pages, these irregularities do occur, and in consequence of them, the bog may reach a certain stage of development and then be set back to a much earlier one, or rejuvenated, or it may reach a mature stage, and continue in it indefinitely, the dry periods causing the surface accumulations to disintegrate sufficiently so that succeeding wet ones are only able to restore what was lost by disintegration and compacting. The plant associations in this stage of development are made up of permanent species, which can endure both wet and dry cycles, and of transient ones, which come and go with the changes of environment brought about by alternate rise and fall of the ground water level.

Still farther, a prolonged dry period may bring about a rapid development of the shoreward zones toward the open water, and an apparent skipping of the usual order of progress in the plant associations. Lastly, in the case of the associations of the mature conditions, certain plants may so raise the surface of their habitat in wet periods, that in dry ones, this becomes very dry, so that only the most drought-resisting species can permanently live in such places, and these migrate into the bogs from the sand plains. On the other hand, however, even these mature associations may slowly bring about changes of their habitat, by affecting drainage, and by producing excessive shade, so that even in such advanced stage, changes may occur. If the drainage is affected so that the water level is raised rapidly, rejuvenation will occur and some of the early stage societies will more or less quickly establish themselves.

Where the growth of tall species, such as Cedar or Spruce, is so luxuriant that the ground is strongly shaded, the lesser species which require much light, are suppressed, which may also mean that the amount of material added to the surface deposits is reduced until the upbuilding no longer goes on. When there is a large development of conifers, the shade may be so dense that no plants grow below them, and the result is a very slow upbuilding, if there is any. Again, if any agency, as wind, insects, disease, competition of neighbors, man, changes of water level, etc., remove these taller species, either as individuals or groups, the increased light usually permits the return of shrubs and herbs for a time.

Species Concerned in Peat Formation: It must also be remembered that many species of plants, as well as zones, are absent from both the marginal and aquatic areas of the boggy lakes of the north, which are present in the south. In fact, if the foregoing descriptions are inspected with this in mind, it will be found that while many species common in the southern bogs are wanting in the northern, they are not replaced, to any extent, by more northern plants, but the flora of the northern bogs are really poorer in species than in the southern, the types which do occur growing in greater numbers, and often more luxuriantly, thus fully occupying the ground.

Not all of the plants which grow in the southern bogs are southern in distribution, however, for a number of species found there in abundance, are, in the north, found growing to greater perfection outside the bogs, and in some cases at least, seldom or never in them. These plants after leaving the bogs are found first on the higher spots and landward margins, and then to take two different types of habitat, the one group going into the broad-leaved forest, where the conditions are best, while the other group seems to move out of the bogs into the dryest and poorest of sites, the sand barrens. In the first group are found the Yellow Birch, the Mountain Maple

and others, while in the second, various shrubs are the most conspicuous plants, such as the Choke-berry and several heaths, some of which, as the Labrador Tea and the Blueberries, give indications, before leaving the bog habitat, of their relationship to the flora of the dry sandy soils, by always growing in the dryest, highest parts of the bogs. The structure of the leaves and other parts of these plants, as shown in another section, indicates a fitness to live in a very dry habitat.

On the other hand, if aquatics are excepted, the important, active, peat-forming plants are the same at the north, as in the south; the sedges which are the most common and important pioneer plants, are all found in the same general relations throughout their range in the region covered by this paper; the water-plants, when present, are of the same species or closely related ones of the same genera; the shrubs are of more importance at the north than at the south in forming peat as has been shown elsewhere, but their extension of vertical range, and importance, is not accompanied by any change of species, except in a few cases, in which some of the less important kinds, like Sweet Gale, do not reach the extreme southern part of our limits, but their importance, compared with other species which are constant, is very small.

Relation of Sphagnum to Peat Formation in the Northern Peninsula: Sphagnum has perhaps been mentioned, more than any other plant, in descriptions of bog plant societies in the preceding pages, because it has been given such an important place as a peat forming plant by many writers upon the subject. In studying the relation of Sphagnum to the formation of peat in Northern Michigan, several things were kept constantly in mind; the most important of these was to determine the relation of the plant to water level, where it grew under natural and undisturbed conditions, for upon this depended, very largely, its capacity to form deep deposits of peat. Because of the importance of this relation, every locality visited was carefully examined to see if Sphagnum showed any tendency to grow in water beyond the margin of the advancing higher seed-plants, as it has been reported to do, and in no single instance was it found beyond the edge of the Sedges or Shrubs which formed the marginal zone upon open ponds. Not only was this true, but in extensive Sedge zones, the Sphagnum was rarely found growing beyond the shoreward margin of the zone, where the water covered the surface of the turf, and where it was thus found, it usually grew more luxuriantly above the water level than below it. In a few instances it was growing in the water among Sedges, but in places where it was clear that there had been a recent rise of water over the whole series of plant zones present. In a few cases the Sphagnum was found growing well in the water of ditches cut through peat beds on which the moss was present as a member of the surface association, and apparently it was at home in the water, where it was seen in such situations, but even in these places, other types of plants were more abundant as aquatics than this, and the farther north the investigation of this subject was carried, the less Sphagnum was in the water, except by the accident of excessive rise of the water due to a heavy rainfall, as in the last open spot in a marsh near Houghton. Sphagnum was found, on the other hand, to appear in the Sedge zone just above the water level and to grow up from this level to a height of from 2 to 3 feet, around shrubs and other plants. At the top of the highest elevations thus built up above the water table of the bogs, another moss, the Hair-cap Moss, or even a lichen, the Reindeer Lichen, was usually found, showing that Sphagnum had reached its limit of growth in the upward direction. The moss was able then to build up a deposit to a height of a little less than 3 feet above the water and then dry ground types of plants settle down on it, and no farther development takes place, unless the water is again raised.

In the extreme southern part of the Northern Peninsula, about Menominee, there was little Sphagnum seen, even in the mature types of bogs, but farther north it was very generally present as a member of the shrub societies; and where the shrubs were pushing out over the water, the moss was among the first plants to follow along after them, but it was very rarely seen growing in the water among the branches of the shrubs, and never beyond them; usually it was found appearing first at a distance of from a yard to a rod, or more, back from the water's edge, on the turf formed by other plants. Sphagnum in this region is entirely a superficial plant, appearing rather late in the history of the development of the bogs, and rarely adds 3 feet of material to the surface. In many cases, the entire deposit of moss remains, together with the living plants, was less than a foot deep, in what seemed to be very old bogs, especially in the north, so that it is evident that the importance of the Sphagnum type of moss as peat formers in the region visited was relatively small. As in the case of other types of plants and even more quickly, because of its rapid growth under favorable conditions, the moss sooner or later creates conditions by its growth, which are unfavorable for it, and it is either replaced by other plants or survives in an enfeebled state, until the conditions change and become more in accordance with its requirements. The main factor which seemed to control the distribution of Sphagnum in the bogs visited, was, as has been stated, height of the ground water level, the amount and kinds of mineral matter present in the water or surrounding soil having apparently no relation to the occurrence of the plant, for it was quite as frequent and widespread in the bogs of the drumlin region, where bed rock was limestone and the soil and soil-waters were highly charged with calcium salts, as in the region of rock hills, where granite and metamorphic rocks furnished the greater part of the materials composing the soils, or in the region still farther north, where sands, largely derived from the Potsdam sandstone, were the characteristic soils, and the soil-waters seemed to have little mineral matter in them. In fact, as Sphagnum grows in the bogs of

Northern Michigan, starting above the water level and away from the margin of the open water of lakes, and from the shoreward borders of bogs and building up a mass of vegetable débris until the living plants are at the top of a mound 2 or more feet from the water, it is difficult to see how the soil-water can affect it much, one way or the other, and it would seem as if it must get most of its moisture from the meteoric water coming to it from above, the small amount reaching it from below being sufficient to supply it with the little mineral matter it requires. Even in valley bogs along streams, the conditions are not favorable for large supplies of soil water to reach the Sphagnum-bearing part of the bog, but the moss was found growing in a few cases near springs where the water which it received was noticeably mineralized. The elevated and dry peat deposits of the Huron Mountain region seem to originate in the growth of Sphagnum and other mosses, and lichens on the bare crystalline rock, but this is by no means certain from the few observations made, bearing upon the matter, and if true but farther shows the lack of relation between the Sphagnum and the soil water. In this discussion, it is understood that no one species of Sphagnum is considered, but all which came under observation were noted, so that the statements made above are generally applicable.

Distribution and Abundance of Peat: One of the first things which strikes an observer in this region, is the number and extent of the swamps, which, because of their distinctive plant associations, are easily noticeable, and marked out from other types of soils. From a study of the map showing the distribution of the bogs and swamps of the Northern Peninsula, it is evident that the impression gained by traveling over the region is a correct one, and that swamps are an important part of the surface features, but are more frequent in some parts than in others. By far the greatest area of peat swamps, since most of these swamps are peat-bearing, in the state, is in the extensive tract lying in the eastern part of the Northern Peninsula, southeast from Munising and extending eastward nearly to Sault Ste. Marie. This area has a length of nearly 100 miles and its greatest width from north to south is nearly 50 miles, if connected, outlying areas are taken into account, but it is usually much narrower than this. This great expanse is not all swamp, but over much of its extent consists of alternating low, narrow, sand ridges, or, more rarely, clayey ones, and broad swamps and marshes. The flatness of the area, and the fact that an outcrop of hard limestone on the south has interrupted the drainage, by preventing the streams flowing out from it from cutting their valleys, seem to be the chief causes operating to make this a region of swamp. The peat, over much of this area, is very shallow, judging from observation and report, and it seems probable that a considerable part of it is not deep enough to warrant commercial development. The parts of the Northern Peninsula least swampy are the south one-third of Houghton and the greater part of Ontonagon and Baraga counties. These are regions of rather steep clay slopes and rock hills with well-drained valleys between them and conditions are not favorable for peat formation. Over tile rest of the Northern Peninsula, areas of swamp are well distributed and vary in area from a few, to many hundreds of acres and the peat in them from a foot, or less, to 20 or more feet in depth. On the whole, this region is more swampy, because less well drained and more moist, than the Southern Peninsula, and the peat has accumulated in shallow deposits where there would be none farther south, or only a thin layer of humus.

The greater moistness of this region is not due, apparently, to much greater rainfall, but to a lower average temperature during the hot part of the year, and especially to the absence of long continued heated spells, which reduces the amount of evaporation from the soil and prevents drying out and complete disintegration of vegetable débris during periods of prolonged drought; cool summer nights with frequent and very heavy dews, and absence of hot drying winds, doubtless also are contributing causes in the same direction.[1]

[1]Data on these points were early published by A. Winchell and may be obtained from the Director of the State Weather Service, C. F. Schneider.

Economic Considerations.

In considering the economic possibilities of the vast stores of peat in this region, several factors have to be taken into account, aside from the efficiency of this substance as a fuel, which may be assumed to be proven by its extensive use in Europe. First among these, is the quantity available near the centers of consumption. As will be seen by reference to the map, nearly all of the larger towns are near bogs of large extent, and as each acre covered by peat represents on the average 200 tons of prepared fuel for each foot in depth, the amount of fuel piled up in these bogs is, in the aggregate, very great.

Necessity of Careful Prospecting: On the other hand must be considered the facts that most of the surfaces of these bogs are uncleared, and are covered by débris which is cleared away with great difficulty, and after the clearing, the upper layers of the peat are so poorly decomposed, as to be of little value for use in manufacturing a finished product that could be easily handled by machinery and which would bear transportation. The quality of the deeper strata of peat of these bogs, is also such that it is doubtful if it could be economically compressed by existing methods because of the incompleteness of the decomposition, and the fact that in many of the bogs, stumps and buried logs are distributed throughout the entire depth. It would be necessary to exercise unusual care in prospecting these bogs of the north, before attempting to develop them, to determine the character of the material and its adaptability to the purposes for which it was planned to use it. The quantity is very large, the quality, in many

places, is poor for use in some of the processes of preparation.

Other Fuels Available in This Region: To an observer from a comparatively treeless, settled region, the amount of forest still untouched by the axe in Northern Michigan is astounding, and it would seem as if there were fuel enough in these to last indefinitely, and at the present rate of consumption, such is the case. The experience in other regions, and even in parts of this, shows, however, that when once the forests are attacked according to modern methods of utilization, they soon disappear as sources of fuel supply, and it may not be long before wood will be as scarce in Northern, as it is in parts of the Southern Peninsula; at present, however, except in very limited areas, the wood supply is too large to warrant the development of peat resources for fuel for common uses. If there were no wood to be had, peat fuel would still have a strong competition in coal brought from the Pennsylvania and Ohio fields, as return cargoes by vessels and cars which carry iron ore from the mines to manufacturing centers, and thus supply a large part of the region with the most efficient and desirable fuel known, with which peat fuels cannot at present compete successfully.

If it were possible to establish peat fuel plants upon the same scale that they are reported in Europe, near some of the Northern Peninsula ports on the Great Lakes, it is probable that an industry of importance could be created in shipping the prepared fuel to the larger cities along the lakes, just as is done with wood and mill waste. At present, however, no such work seems feasible, although the cheap water transportation should foster such an enterprise and help to make it a success if it could once be started.

Peat Coke in Relation to the Iron Industry: A much more promising possible use for peat, which has passed the experimental stage abroad, is the manufacture of charcoal iron from peat coke. Peat is readily transformed into a form of charcoal or coke, just as wood, or soft coal is, by heating in closed oven. This substance, when made from peat, is in every way as good as coke, which it closely resembles, and possesses the great advantage of being as free from objectionable substances for iron manufacture as charcoal—in fact it is a charcoal, rather than a true coke, since peat is nearer wood than coal in its composition. Already there is a great and growing charcoal iron industry developing in the state, using enormous quantities of wood, which can probably be more economically and quite as profitably used in other industries, and which threatens the extinction of the remainder of our forests at an early date. The great areas of peat in the Menominee and Marquette iron regions, are, in the meantime, entirely unutilized and are exposed to constant danger of damage by fire and overdrainage, as their potential value is not realized and they are considered worthless, when, by following the methods used by the Germans, a very profitable use might be made of them, and of other deposits as well, since in the manufacture of the coke, the objections to which the less thoroughly decomposed peats are open, in making peat briquettes, do not obtain, as the finished product is hard and compact and does not easily deteriorate in handling. If this material could be utilized in this way, existing charcoal plants could possibly be used with but a slight modification, and the by-products, including gas, would be nearly identical in kind, with those now obtained from wood distillation. The main change which would be necessary, would be to install machinery for digging, handling and drying the peat. The general development of the manufacture of the peat coke on a large scale in this region, should be seriously considered by capitalists and others interested in the conservation of the wood supply and the utilization of what should be considered an important undeveloped resource.

Agricultural Possibilities of the Peat Bogs in This Region: In most cases, the region traversed by the writer was not sufficiently drained to permit of the use of the peat swamp land for agriculture. The swamps were still in an uncleared and unsubdued condition, and seemed likely to remain so, for several reasons, among which coldness, lack of drainage, and expense of subduing, were the most frequent given. In a few places, however, there had been some agricultural use made of the swamps with varying results. In one instance an area of swamp had been cleared, drained and put under cultivation at considerable expense, only to prove entirely useless for growing crops, because of the undecomposed condition of the peat—it was too dry for any cultivated plants to grow upon; burning off the surface layer, had been tried, but the whole deposit was so poorly decomposed that this did little, if any, good, and, in the opinion of the writer, this will prove to be the case in many of the peaty swamps of this region. The method of treatment which should prove most efficacious with land of this sort, is the use of plenty of barnyard manure, which, by introducing fermentive organisms and fungi, into the peat, helps decomposition, increases its moisture holding power, as well as furnishes readily absorbed food for the crop plants. Around Newberry, the peat has been successfully used for producing a variety of crops, and seemed, where cultivated, to be in all respects in good condition for the purpose, and the celery grown here, in this type of soil, has a well-merited reputation for its excellent quality and flavor.

In conclusion, it may be well to point out that the swamps are the last kind of lands to be fully utilized in any region, and that in many of the older and more thickly settled parts of the state, the bogs and swamps are still in a wild state and are waste land to all intents and purposes, for the reason that, in many cases, attempts to use them have been misdirected and failures on this account. This problem of using this class of land is a difficult one to solve, and while the returns are excellent, if a correct solution is found, the chances are many that failure to see some of the factors of solution,

will give an entirely unsatisfactory return for the efforts made, and a few such unsuccessful attempts discourage farther effort in a given locality. If this is true, in the southern part of the state, where the bogs generally have a much better and more fully disintegrated peat, and where decomposition goes on more rapidly than in the north, it is very likely to be more frequently so in the northern part, and it would be unsafe to try cultivation of peat swamps on a large scale in this region, until the conditions to be met there have been thoroughly tested by experiments, carefully conducted after a sufficiently thorough preliminary investigation. In Europe these matters are now generally turned over to commissions or societies of trained experts, partly paid by government and partly by private subscription of land owners and all of the possibilities of a given type of lands are thoroughly investigated and tested and the results reported upon, before private individuals take the matter up. The majority of the countries of Northern Europe now have strong societies, whose sole purpose is the development of the swamp lands of the countries, and great strides have been made in rendering some of such areas productive, through the work of these organizations. Similar work ought to be done in this country, and undoubtedly will be, as the need of properly utilizing the large areas of swamp and bog lands throughout the northern part of the country, becomes more pressing, because of the exhaustion of other lands and the increase in population.

Other Uses that Might be Made of Peat:

There are other uses to which the extensive peat bogs in the vicinity of the cities might be put to advantage, all, however, requiring rather large investment of capital to make them possible. Among these are the use of the substance in certain manufactures, such as paper pulp or paper, fabrics, etc.; its use in such a way is not, however, probable, when other extensive natural resources, such as the extensive hardwood forests, are not yet being developed.

The establishment of central plants on extensive bogs for the generation of electricity to be transferred to mines and mills at a distance is also one of the possible other uses which might be made of the stores of peat which have been described, but again it does not seem likely that capital., will seek such an investment, until some of the many really fine waterfalls, capable of producing, in the aggregate, a vast number of horsepowers of electric current, have been harnessed and this cheap and efficient source of energy developed to something near its capacity, because the water power is more cheaply developed, and is much more permanent than any peat, or other similar deposit could ever be.

Peat, as a source of gas for heating, for use in explosive engines, and for lighting, is a possibility of no mean importance, since the gas can be generated at the bog and piped long distances, and since peat gas is rated as excellent for all purposes mentioned, especially for use in engines. In addition to the gas in such a plant, coke and various secondary products would be obtained which would add to the value of this form of the utilization of peat bogs. It seems unlikely that even this comparatively inexpensive way of developing an industry based on the peat bogs of the Northern Peninsula will be considered practicable and practical in the near future, although for years in Sweden and other parts of Northern Europe peat gas has been used with success for various purposes and is made by comparatively simple and cheap apparatus, but the sparse population, the lack of industrial development, except in certain lines, and prejudice in favor of established methods and against the innovation will tend to prevent such a utilization of peat as that suggested even in connection with mining operations, where it could be most profitably used in a variety of ways.

In this section of the report, stress has been laid upon the history of the development of the bogs, because so little was known of it in this region, and also because the technical aspects of the question are more fully developed in another section of the work.

Below is given a list of the plants mentioned in this section of the reports, giving the scientific names equivalent to the common names of species which have been listed and discussed in connection with descriptions of lakes, bogs and other features which have been considered in the preceding pages, for the use of botanists, teachers and others who may wish to be sure of the identity of the plants named.

LIST OF COMMON NAMES AND THE EQUIVALENT SCIENTIFIC NAMES OF PLANTS MENTIONED IN THE REPORT OF THE NORTHERN PENINSULA PEAT BOGS.

(Names generally correspond with those used in Beal's Michigan Flora, 5th report Michigan Academy of Science, 1904, Reprinted by State Board of Agriculture, 1904.)

1. Common Alder, *Alnus incana* (L.) Willd.
2. Andromeda, *Andromeda polifolia* L.
3. Canada Anemone, *Anemone Canadensis* L.
4. Arbor Vitae or White Cedar, *Thuja occidentalls* L.
5. Trailing Arbutus, *Epigæa repens* L.
6. Arethusa, *Arethusa bulbosa* L.
7. Arrow-grass, *Sagittaria latifolia* Willd.
8. Marsh Arrow-grass, *Triglochin palustris* L.
9. Broad-leaved Arrow-head, *Sagittaria latifolia* Willd.
10. Aspen or American Aspen, *Populus tremuloides* Michx.
11. Large-toothed Aspen, *Populus grandidentata* Michx.
12. Black Ash, *Fraxinus nigra* Marsh.
13. Mountain Ash, *Sorbus Americana* Marsh.

14. Balsam or Fir Balsam, *Abies balsamea* (L.) Miller.

15. Basswood, *Tilia Americana* L.

16. Bearberry, *Arctostaphyllos Uva-Ursi* (L.) Spreng.

17. Beech, *Fagus Americana* Sweet.

18. Marsh Bell-flower, *Campanula aparinoides* Pursh.

19. Black Birch, *Betula lenta* L.

20. Dwarf Birch, *Betula pumila* L.

21. White Birch, *Betula papyrifera* Marsh.

22. Yellow Birch, *Betula lutea* Michx.

23. Small Bishop's-cap, *Mitella nuda* L.

24. Tall Blackberry, *Rubus nigrobaccus* Bailey.

25. Canada Blueberry, *Vaccinium Canadense* Richards.

26. Low Blueberry, *Vaccinium Pennsylvanicum* Lam.

27. Low Black Blueberry, *Vaccinium nigrum* (Wood) Britton.

28. Flat-leaved Bladderwort, *Utricularia intermedia* Hayne.

29. Greater Bladderwort, *Utricularia vulgaris* L.

30. Horned Bladderwort, *Utricularia cornuta* Michx.

31. Smaller Bladderwort, *Utricularia minor* L.

32. Larger Blue Flag, *Iris versicolor* L.

33. Brake or Common Brake, *Pteridium aquilinum* (L.) Kuhn.

34. Buckbean, *Menyanthes trifoliata* L.

35. Buckthorn, *Rhamnus alnifolia* L'Her.

36. Dark-green Bulrush, *Scripus atrovirens* Muhl.

37. Lake Bulrush, *Scirpus lacustris* L.

38. Bunch-berry, *Cornus Canadensis* L.

39. Smaller Bur-Marigold, *Bidens cernua* L.

40. Bur-reed, *Sparganium Sp*.

41. Small Bur-reed, *Sparganium minimum* Fries.

41a. Submerged Bur-reed, *Sparganium simplex angustifolium* (Michx.) Engelm.

42. Pursh's Buttercup, *Ranunculus Purshii* Richards.

43. Calopogon, *Limnodorum tuberosum* L.

44. Cassandra, *Chamædaphne calyculata* (L.)

45. Cat-tail, *Typha latifolia* L.

46. Cedar or White Cedar, *Thuja occidentalis* L.

47. Dwarf Sand Cherry, *Prunus pumila* L.

48. Wild Red or Pin Cherry, *Prunus Pennsylvanica* L.

49. Choke-berry, *Aronia arbutifolia* (L.) Medic., and *Aronia nigra* (Willd.) Britton.

50. Three-toothed Cinquefoil, *Sibbaldiopsis tridentata* Rydb.

51. Shrubby Cinquefoil, *Dasiphora fruticosa* (L.) Rydb.

52. Clintonia, *Clintonia borealis* (Ait.) Raf.

53. Bog Club-moss, *Lycopodium inundatum* L.

54. Water Club-rush, *Scirpus subterminalis* Torr.

55. Alpine Cotton-grass, *Eriophorum alpinum* L.

56. Slender Cotton-grass, *Eriophorum gracile* Koch.

57. Tall Cotton-grass, *Eriophorum polystachyon* L.

58. Virginia Cotton-grass, *Eriophorum Virginicum* L.

59. Silky Cornel, *Cornus Amonum* Mill.

60. Spotted Cowbane, *Cicuta maculata* L.

61. Cow-wheat, *Melampyrum lineare* Lam.

62. Large Cranberry, *Oxycoccus macrocarpus* (Ait.) Pers.

63. Small Cranberry, *Oxycoccus Oxycoccus* (L.) MacM.

64. Bristly Crowfoot, *Ranunculus Pennsylvanicus* L.

65. Great Water Dock, *Rumex Brittanica* L.

66. Dulichium, *Dulichium arundinaceum* (L.) Britton.

67. Rock Elm, *Ulmus racemosa* Thomas.

68. White Elm, *Ulmus Americana* L.

69. Cinnamon Fern, *Osmunda Cinnamomea* L.

70. King Fern, *Osmunda regalis* L.

71. Marsh Shield-fern, *Dryopteris Thelypteris* (L.) A. Gray.

72. Sensitive Fern, *Onoclea sensibilis* L.

73. Sweet-fern, *Comptonia perigrina* (L.) Coulter.

74. Philadelphia Fleabane, *Erigeron Philadelphicus* L.

75. Spurred Gentian, *Tetragonanthus deflexus* (J. E. Smith) Kuntze..

76. Goldthread, *Coptis trifolia* (L.) Salisb.

77. Late Golden-rod, *Solidago serotina* Ait.

78. Small Goose-grass, *Galium trifidum* L.

79. Blue-Joint Grass, *Calamagrostis Canadensis* (Michx.) Beauv.

80. Floating Manna-grass, *Panicularia fluitans* (L.) Kuntze.

81. Nerved Manna-grass, *Panicularia nervata* (Willd.) Kuntze.

81a. Tall Manna-grass, *Panicularia Americana* (Torr.) MacM.

82. Tall Reed-grass, *Phragmites Phragmites* (L.) Karst.

83. Beaked Hazel-nut, *Corylus rostrata* Ait.

84. Hemlock, *Tsuga Canadensis* (L.) Carriere.

85. Cut-leaved Water Hoar-hound, *Lycopus Americanus* Mulil.

86. Mountain Holly, *Ilicioides mucronata* (L.) Britton.

87. Bush Honeysuckle, *Diervilla Diervilla* (L.) MacM.

88. Swamp Honeysuckle, *Lonicera oblongifolia* (Goldie) Hook.

89. Common Horsetail, *Equisetum arvense* L.

90. Huckleberry, *Gaylussacia resinosa* (Ait.) Torr. & Gr.

91. Ironwood, *Ostrya Virginica* (Mill.) Willd.

92. Labrador Tea, *Ledum Grœnlandicum* L.

93. Showy Ladies' Slipper, *Cypripedium reginae* Walt.

94. Stemless Ladies' Slipper, *Cypripedium acaule* Ait.

95. Pale Laurel, *Kalmia glauca* Ait.

96. Ladies' Tresses, *Gyrostachys cernua* (L.) Kuntze.

97. Reindeer Lichen, *Cladonia* spp.

98. Wild Lily-of-the-Valley, *Unifolium Canadense* (Desf.) Greene.

99. Fringed Loosestrife, *Steironema ciliatum* (L.) Raf.

100. Swamp Loosestrife, *Decodon verticillatus* (L.) Ell.

101. Tufted Loosestrife, *Naumbergia thyrsiflora* (L.) Duby.

102. Hard Maple, *Acer saccharum* Marsh.

103. Mountain Maple, *Acer spicatum* Lam.

104. Red Maple, *Acer rubrum* L.

105. Purplish Meadow-Rue, *Thalictrum purpurascens* L.

106. Meadow-Sweet, *Spiraea salicifolia* L.

107. Swamp Milkweed, *Asclepias incarnata* L.

108. Wild Mint, *Mentha Canadensis* L.

109. Small Mistletoe, *Razoumofskya pusilla* (Peck) Kuntze.

110. Monkey Flower, *Mimulus ringens* L.

111. Hair-cap Moss, *Polytrichum* spp.

112. Slender Naias, *Naias flexilis* (Willd.) Rost & Schm.

113. Hedge Nettle, *Stachys aspera* Michx.

114. Red Oak, *Quercus rubra* L.

115. Scarlet Oak, *Quercus coccinea* Wang.

116. Tall Green Orchis, *Limnorchis hyperborea* (L.) Rydb.

117. Tall Leafy Green Orchis, *Limnorchis hyperborea*, (L.) Rydb.

118. Tall White Bog Orchis, *Limnorchis dilatata* (Pursh) Rydb.

1.19. Red Osier, *Cornus stolonifera* Michx.

120. Marsh Pea, *Lathyrus palustris* L.

121. Harthwright's Persicaria, *Polygonum Hartwrightii* A. Gray.

122. Swamp Persicaria, *Polygonum emersum* (Michx.) Britton.

123. Pickerel Weed, *Pontederia cordata* L,

124. Jack Pine, *Pinus divaricata* (Ait.) Gord.

125. Norway Pine, *Pinus resinosa* Ait.

126. White Pine, *Pinus Strobus* L.

127. Indian Pipe, *Monotropa uniflora* L.

128. Pipe-wort, *Eriocaulon septangulare* Willd.

129. Pitcher Plant, *Sarracenia purpurea* L.

130. Fringed Polygala, *Polygala pauciflora* Willd.

131. White Pond Lily, *Castalia* spp.

132. Yellow Pond Lily, *Nmyphæa advena* Soland.

133. Common Floating Pondweed, *Potamogeton natans* L.

134. Pondweeds, *Potamogeton* spp.

135. Balsam Poplar, *Populus balsamifera* L.

136. Joe Pye-Weed, *Eupatorium purpureum* L.

137. Low Raspberry, Dwarf Raspberry, *Rubus Americanus* (Pers.) O. A. F.

138. Red Raspberry, *Rubus strigosus* Michx.

139. Rush, *Juncus* spp.

140. Slender Rush, *Juncus tenuis* Willd.

141. Soft Rush, *Juncus effusus* L.

142. Swamp Saxifrage, *Saxifraga Pennsylvanica* L.

143. Bristly Sarsaparilla, *Aralia hispida* Vent.

143a. Scheuchzeria, *Scheuchzeria palustris* L.

144. Bottle Sedge, *Carex utriculata* Boott.

145. Bristly Sedge, *Carex comosa* Boott.

146. Bristle-stalked Sedge, *Carex leptalea* Wahl.

147. Creeping Sedge, *Carex chordorhiza* L. f.

148. Fox Sedge, *Carex vulpinoidea* Michx.

149. Few-seeded Sedge, *Carex oligosperma* Michx.

150. Lesser Panicled Sedge, *Carex teretiuscula* Good.

151. Little Prickly Sedge, *Carex sterilis* Willd.

152. Magellan's Sedge, *Carex Magellanica* Lam.

153. Pennsylvania Sedge, *Carex Pennsylvanica* Lam.

154. Porcupine Sedge, *Carex hystricina* Muhl.

155. River-bank Sedge, *Carex riparia* W. Curtis.

156. Sartwell's Sedge, *Carex Sartwellii* Dewey.

157. Slender Sedge, *Carex filiformis* L.

158. Soft-leaved Sedge, *Carex tenella* Schk.

159. Three-leaved Sedge, *Carex trisperma* Dewey.

160. Tussock Sedge, *Carex stricta* Lam.

161. Water Sedge, *Carex aquatilis* Wahl.

162. Yellow Sedge, *Carex flava* L.

163. Marsh Skull-cap, *Scutellaria galericulata* L.

164. Common Smart-weed, *Polygonum hydropiper* L.

165. Sneeze-weed, *Helenium autumnale* L.

166. Creeping Snowberry, *Chiogenes hispidula* (L.) Torr & Gr.

167. Sheep Sorrel, *Rumex acetosella* L.

168. Three-leaved Solomon's Seal, *Vagnera trifolia* (L.) Morong.

169. Sphagnum, *Sphagnum* spp.

170. Creeping Spike-rush, *Eleocharis palustris* (L.) R. & S.

171. Black Spruce, *Picea brevifolia* Peck.

172. Black Spruce, *Picea Mariana* (Mill.) B. S. P.

173. White Spruce, *Picea Canadensis* (Mill.) B. S. P.

174. Starflower, *Trientalis Americana* (Pers.) Pursh.

175. Northern Water-Starwort, *Callitriche bifida* (L.) Morong.

176. Water-Starwort, *Callitriche palustris* L.

177. Canadian St. John's-wort, *Hypericum Canadense* L.

178. Marsh St. John's-wort, *Triadenum Virginicum* (L.) Raf.

179. Barren Strawberry, *Waldsteinia fragarioides* (Michx.) Tratt.

180. Round-leaved Sundew, *Drosera rotundifolia* L.

181. Sweet Flag, *Acorus Calamus* L.

182. Sweet Gale, *Myrica Gale* L.

183. Tamarack, *Larix Laricina* (DuRoi) Koch.

184. Swamp Thistle, *Carduus muticus* (Mx.) Pers.

185. Touch-me-not, *Impatiens biflora* Walt.

186. Twin-flower, *Linnæa Americana* Forbes.

187. Swamp Valerian, *Valeriana uliginosa* (T. & G.) Rydb.

188. Blue Vervain, *Verbena hastata* L.

189. Kidney-leaved Violet, *Viola renifolia* A. Gray.

190. Lance-leaved Violet, *Viola lanceolata* L.

191. Marsh Violet, *Viola Le Conteana* Don.

192. Sweet Wild Violet, *Viola blanda* Willd.

193. Yellow Water-cress, *Roripa palustris* (L.) Bess.

194. Bulb-bearing Water Hemlock, *Cicuta bulbifera* L.

195. Sweet-scented Water Lily, *Castalia odorata* (Dryand.) Woodv. & Wood.

196. Water Shield, *Brasenia purpurea* (Michx.) Casp.

197. Bebb's Willow, *Salix Bebbiana* Sarg.

198. Hoary Willow, *Salix candida* Fluegge.

199. Myrtle-leaved Willow, *Salix myrtilloides* L.

200. Shining Willow, *Salix lucida* Muhl.

201. Silky Willow, *Salix sericea* Marshall.

202. Great Willow Herb, *Chamænerion angustifolium* (L.) Scop.

203. Marsh Willow Herb, *Epilobium palustre* L.

204. Winterberry, *Ilex verticillata* (L.) A. Gray.

205. Wintergreen, *Gaultheria procumbens* L.

206. Bog Wintergreen, *Pyrola uliginosa* Torr.

207. Withe-rod, *Viburnum cassinoides* L.

208. Wood-rush, *Juncoides pilosum* (L.) Kuntze.

209. Upright Yellow Wood-sorrel, *Oxalis stricta* L.

210. Wool-grass, *Scirpus cyperinus* (L.) Kunth.

List of Plants from Huron Mountains.

211. Small Bedstraw, *Galium trifidum* L.

212. June Berry, *Amelanchier Canadensis* (L.) Medic.

213. Black Bindweed, *Polygonum Convolvulus* L.

214. Bugleweed, *Lycopus* sp.

215. Choke Cherry, *Prunus Virginiana* L.

216. Wild Bed Cherry, *Prunus Pennsylvanica* L. f.

217. Mouse-ear Chickweed, *Cerastium vulgatum* L.

218. Rough Cinquefoil, *Potentilla Monspeliensis* L.

219. Red Clover, *Trifolium pratense* L.

220. White Clover, *Trifolium repens* L.

221. Pale Corydalis, *Capnoides sempervirens* (L.) Borck.

222. Fetid Currant, *Ribes prostratum* L'Her.

223. Red-berried Elder, *Sambucus pubens* Michx.

224. Fire-weed, *Chamænerion angustifolium* (L.) Scop.

225. Blue Grass, *Poa pratense* L.

226. Hair Grass, *Agrostis hyemalis* (Walt.) B. S. P.

227. Wild Oat-grass, *Danthonia spicata* (L.) Beauv.

228. Rock Panic-grass, *Panicum* sp.

229. Wire-grass, *Poa compressa* L.

230. Swamp Horsetail, *Equisetum fluviatile* L.

231. Low Juniper, *Juniperus nana* Willd.

232. Water Lobelia, *Lobelia Dortmanna* L.

233. American Mountain Ash, *Sorbus Americana* Marsh.

234. Pigweed, *Chenopodium album* L.

235. Common Polypody, *Polypodium vulgare* L.

236. Quillwort, *Isoetes* sp.

237. Red Top, *Agrostis alba* L.

238. Bladder Sedge, *Carex folliculata* L.

239. Sheep Sorrel, *Rumex Acetosella* L.

240. Spike-rush, *Eleocharis acicularis* (L.) R. & S.

241. Marsh St. John's-wort, *Triadenum Virginicum* (L.) Raf.

242. American Wood Strawberry, *Fragaria Americana* (Porter) Britton.

243. Timothy, *Phleum pratense* L.

244. Dog Violet, *Viola Labradorica* Schrank.

245. Sweet White Violet, *Viola Blanda* Willd.

246. Yellow Water-cress, *Roripa palustris* (L.) Bess.

247. Purple-leaved Willow-herb, *Epilobium coloratum* Muhl.

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