

## THE PEAT DEPOSITS OF MINNESOTA.

E. K. SOPER.

### INTRODUCTION.

It has been known for some time that Minnesota contains large deposits of peat, but, up to the present, no detailed information has been available regarding the quantity and quality of Minnesota peat, and the uses to which it is best adapted. An investigation was undertaken to determine these facts and some of the results are outlined below. The work was done by the writer for the Minnesota Geological Survey and Mr. Percy G. Cowin assisted in the field.

### CONDITIONS OF PEAT FORMATION IN MINNESOTA.

#### *Occurrence.*

Peat deposits form only in depressions filled with water, such as lakes and ponds, or on low, flat, or very gently sloping surfaces, where the water table is constantly at the surface, therefore always wet. Plate XXXI. shows various types of Minnesota peat bogs.

#### *Climatic Influences.*

The most important climatic influences in peat formation are (1) regular and abundant rainfall, and (2) high humidity of the air. A third should be mentioned, namely, a cold or temperate climate, but this is not absolutely necessary, for peat deposits are known in warm climates such as that of Florida.

The conditions essential to the formation of extensive peat deposits are prevalent in eastern North America north of 40° N.

Latitude and most of the peat in the United States lies north of 40° N. Latitude and east of the Dakotas. The largest and deepest deposits in North America occur within this area, along the Canadian boundary, on both sides of the line.

The influence of climate upon the origin and accumulation of peat is well shown in Minnesota; the largest and deepest peat bogs are all in the northern portion of the state, where the mean annual temperature is 8 to 10 degrees colder than in the southern counties.

The least rainfall is in the northwest corner of the state, where there is no peat whatever. From the North Dakota boundary, the rainfall increases steadily to the eastward as far as the Lake Superior region, a vicinity in which are found some of the largest peat bogs in America. There are some localities in northern Minnesota, chiefly north of Lake Superior, where, in spite of the cold climate and abundant precipitation, there is little or no peat. This is due to the topography of these regions, which is so hilly and rocky that no marshes or bogs could form.

#### *Topographic Influences.*

Just as the climate of a region controls in part the quantity of peat which may form, so the topography controls the distribution of the deposits. Given all conditions favorable except topography, no peat would form, since its formation requires the existence of basins, depressions, or flat, undrained areas, in which the plant remains can accumulate and be protected from decay and decomposition.

The principal topographic divisions in Minnesota are: (1) a complex system of morainic belts and partially filled kettle holes; (2) gently undulating belts of modified glacial drift, such as outwash plains, clayey till plains, etc.; (3) several large lake beds, the most important of which are those of ancient Lake Agassiz in the northwestern part of the state, the large lake which once covered a part of St. Louis County, and the delta deposits of the glacial Lake Superior in the northwestern portion of the state. In some localities, especially in northeastern Min-

nesota, rock hills rise above the glacial drift. The largest and most numerous moraines occur in northern and central Minnesota, and many peat bogs, some of which are very deep, occupy the depressions and basins in these morainic belts.

The altitudes of Minnesota range from 602 feet, the level of Lake Superior, to 2,230 feet, the highest point in Cook County in the northeast corner of the state. This gives a maximum relief of 1,628 feet. Most of the state, however, has a gently undulating surface of slight relief, with extensive flat areas which represent ancient glacial outwash plains, or old lake beds, many of which are covered with peat deposits.

#### *Effect of Glacial Influence upon Peat Formation.*

Nearly all the peat deposits in the northern United States (Minnesota, Wisconsin and Michigan), as well as those of eastern Canada, owe their origin directly or indirectly to the influence of glaciation. Before extensive deposits of peat may be formed, the three essential factors in peat formation, *i. e.*, climate, topography and vegetation, must all be favorable. In northern Minnesota the topography is the direct result of glaciation, while the climate and vegetation have been indirectly controlled by the same glacial influences.

At least 95 per cent. of the peat in Minnesota lies north of Minneapolis and St. Paul, and hence it is necessary to consider only the glacial drift of the northern part of the state in studying the influence of glacial drift upon peat formation. All the peat in Minnesota rests upon glacial drift, or modified drift. In northern Minnesota there are only two important drift sheets exposed at the surface and in contact with the peat. These are: (1) The *Young Red Drift*, in northeastern Minnesota, and (2) the *Young Gray Drift*,<sup>2</sup> in the northwestern and central parts. Both of these drift formations probably belong to the youngest, or Wisconsin Stage of Pleistocene Glaciation. The largest peat bogs overlie the water-sorted gray drift which constitutes the

<sup>2</sup> Leverett, Frank, "Surface Formations and Agricultural Conditions of Northwest Minnesota," Minn. Geol. Survey Bull. 12, p. 32.

bed of ancient Lake Agassiz, which in turn rests upon calcareous gray drift. A careful study of the peat bogs of northern Minnesota, with reference to the nature of the drift upon which they rest, shows that the peat deposits are not confined to any single drift formation, but that they occur over areas of red as well as of gray drift. The largest deposits, however, exist within the area of gray drift, but this is due to topographic conditions rather than to any influence exerted by the composition of the drift.

#### *Relation of Marl Beds to Peat Formation.*

Many lakes in central and northern Minnesota contain valuable deposits of marl, the origin of which is clearly due to precipitation of lime carbonate from solution in the lake waters through the agency of the plant, *Chara*<sup>3</sup> (stonewort). When the *Chara* are displaced by the invasion of other water-loving plants, the accumulation of marl in the lake may be followed by the accumulation of peat. Under such conditions, which were frequently observed in Minnesota, the lake may ultimately become completely filled with marl and peat. The marl always lies on the bottom and is not sharply separated from the overlying peat. The peat may continue to form after the lake is filled by the accumulation of successive layers of dead plant remains on the surface of the bog. The presence, therefore, of a considerable number of peat bogs in Minnesota, underlain by beds of pure marl, is readily explained when the history of these marl deposits is known.

#### *Depth of Peat Accumulation.*

The depth of peat accumulation depends chiefly upon the form of surface at the site of accumulation; the climate; amount, and character of vegetation. The form of land surface is the principal factor controlling the depth.<sup>4</sup> Peat deposits formed in

<sup>3</sup> For an excellent account of the origin of marl see Davis, C. A., Michigan Geol. Survey, Vol. 8, 1900-1903.

<sup>4</sup> See Shaler, N. S., "General Account of the Fresh Water Morasses of the United States," U. S. Geol. Survey, 10th Annual Report, p. 262.

lakes or basins are usually deeper than those formed on flat surfaces or in slight depressions. It should be understood, however, that the depth of a given basin does not necessarily determine the thickness of peat which may accumulate there. Under certain conditions, peat may continue to accumulate after the basin has become filled, by the addition of successive layers of dead vegetation to the surface of the bog, thus building up the deposit above the former lake level, or above the original rim of the basin. Numerous examples of such deposits were observed in the northern part of the state.

The peat deposits of Minnesota vary in thickness from a few inches up to 63 feet. The deposits in the southern portion of the state are generally much shallower than those in the north, because there the topography, climate, and vegetation are all unfavorable to thick accumulations. The maximum thickness noted in the southern bogs is 18 feet. The majority of the deposits of that region, however, are less than 5 feet thick. In the north many of the bogs are 20 to 25 feet thick in the center, especially those of the filled-lake type.

The average depth of peat in the great built-up deposits occupying portions of the bed of Lake Agassiz in north-central Minnesota is 7 to 9 feet but increases to 18 or 20 feet in many places. These deeper areas evidently represent depressions and hollows below the general surface of the old lake bed, which probably remained as temporary ponds and lakes after the main body of water had disappeared from this region.

#### *Rate of Peat Formation.*

The rate of peat formation varies with the amount of vegetation, moisture and other conditions. Dana<sup>5</sup> gives as a *maximum* rate of peat accumulation 1 foot in five or ten years. This maximum has not been reached in Minnesota, in the writer's opinion, and there is evidence that the rate of growth has been very much slower.

Since all of the lakes of the state are of glacial origin, it is not

<sup>5</sup> Dana, James D., "Manual of Geology," 4th ed., p. 154.

unreasonable to assume that they are approximately of the same age, and that peat accumulation began in many of these lakes at about the same time. At those places where the lakes became filled with peat to the original water level, after which peat accumulation stopped, it is impossible to get any significant evidence as to the rate of accumulation, since there is no means of determining how long a time has elapsed since peat formation stopped. In other lakes, however, peat formation did not stop when the lake became filled to the rim of the basin, but peat continued to form, building up the surface of the bog many feet above the original lake level by the addition of successive layers of vegetation. In deposits of this type, where peat is in active process of formation today, the evidence obtained from the study of numerous sections of the deposits indicates that peat accumulation has been continuous from the time it first began, which probably was not long after the origin of the lake. If this assumption be even approximately correct, we have a rough means of estimating the rate of peat accumulation. Reckoning the time which has elapsed since the close of the Pleistocene Glacial Period at 10,000 to 30,000 years, and taking 18 feet as the average thickness of some of the largest filled-lake bogs, and assuming the accumulation to have been uninterrupted by fires or drought, we get a growth of .022 to .0072 inches per year as the average annual rate of peat accumulation in northern Minnesota, in bogs of the filled-lake type.

In the built-up deposits, formed on flat, wet land surfaces by successive layers of plant remains, the rate of peat accumulation is probably much more rapid than in filled-lake deposits.

#### *Classification of Minnesota Peat Deposits.*

The most logical classification of peat deposits is probably that based upon the type of land surface upon which the peat is formed. Upon such a basis the following types of deposit may be recognized:

1. Deposits which represent filled lakes or ponds (Fig. A, Pl. XXXII.).

2. Deposits which represent accumulations built up on moist depressions, or flat, undrained areas (Fig. B, Pl. XXXII.).
3. Deposits which represent combinations of types 1 and 2, and which consist of lake, or pond peat, in the lower portion, and swamp, or sphagnum peat, above. These often resemble type 1 or 2 in appearance, and their true nature may only be ascertained by soundings.
4. Deposits which occur on flats and lowlands along river valleys.

#### ASSOCIATIONS OF PEAT-FORMING PLANTS.

Peat deposits may be divided into two main groups according to the type of surface upon which the peat accumulated. These are: (1) peat deposits formed in basins filled with water, and (2) peat deposits formed on flat, or gently sloping, undrained, land surfaces. The plant associations active in forming these two types of deposit are entirely different, especially in the earlier stages of development of the bogs. In order to clearly trace the origin of peat and the various developmental stages in the history of the peat deposits, the plant associations which are characteristic of these two types of bog should be considered.

#### *Plant Deposits in Lakes and Ponds.*

Peat bogs in coniferous forest regions go through the following developmental stages, if not arrested through the influence of some external agency.<sup>6</sup>

1. Stonewort—waterweed stage. (*Chara-Philotria* Associates.)
2. Pondweed—waterlily stage. (*Potamogeton-Nymphaea* Associates.)
3. Rush—wild rice stage. (*Scirpus-Zizania* Associates.)
4. Bog meadow stage. (*Carex* Associates.)
5. Sphagnum—bog heath stage. (*Andromeda-Ledum* Associates.)
6. Tamarack—spruce stage. (*Larix-Picea* Associates.)

In the deciduous forest regions the peat bogs go through essentially the same stages until the lake is filled with peat, when the

<sup>6</sup> Bergman, H. F., Department of Botany, University of Minnesota. Unpublished manuscript.

swamp plants are replaced by those of the climax vegetation, and the accumulation of peat is stopped.

In the prairie regions the swamp vegetation is never replaced by trees. Bog-heaths, tamarack, and spruce are never found. The swamp or bog-meadow stage is the highest stage attained by peat bogs of the filled-lake type in the prairie regions. The developmental stages preceding the swamp stage are the same as for the forested regions. When a prairie swamp fills up and becomes too dry for peat accumulations, the swamp vegetation, consisting chiefly of sedges, reed-grasses, etc., is replaced by the typical prairie grasses, such as blue-stem, Indian grass, and porcupine grass.

*Peat Deposits on Flat, or Gently Sloping, Wet Surfaces.*

A swamp represents an arrest in the natural development of the vegetation of a region. In the case of swamps derived from filled lakes, just described, they are arrested *primary successions*.<sup>7</sup> If the arrest in the vegetational development is caused by some outside influence, such as glaciation, flooding, forest fires, etc., a *secondary succession* may be initiated. Thus, any cause which destroys the existing vegetation of a region may start a secondary succession, and the secondary succession may begin at any point between the first stage and the climax vegetation. Peat bogs which have been built up on flat, wet, or flooded surfaces are secondary successions.

In Minnesota and throughout most of the Lake Superior region, where the largest and deepest bogs in the United States occur, there are many extensive swamps of this type. The chief agency which has initiated these secondary successions has been *glaciation*. The glaciation of this region completely destroyed all the existing vegetation. Upon the melting and recession of the ice, the drainage of the recently denuded surface was blocked, and large areas of flat or depressed land lying south of the retreating ice sheet were flooded, and temporary glacial lakes formed. Other large areas, while not covered with water and

<sup>7</sup> Bergman, H. F., unpublished manuscript, University of Minnesota.



converted into lakes, were kept constantly wet and marshy. Upon such surfaces as these the built-up peat bogs of the northern states have been formed.

The peat in many of these bogs consists chiefly of sedge and grass remains, showing that the deposit remained for a long period in the bog-meadow stage. In other bogs of this type the peat consists almost entirely of the remains of sphagnum, or peat moss, showing that this plant obtained a strong foothold among the first plants to appear after the recession of the ice, and that the development of the resulting bog was more or less permanently arrested in this stage.

Under ordinary conditions the swamps originating by secondary succession (built-up bogs) may pass through the same stages of development as those originating by primary succession (filled lakes), but the built-up deposits may start at any point in their development, and through the influence of certain outside agencies, they may be permanently arrested at any stage, so that only one or two typical plant associations will be represented in the bog. This is why there are so many large peat bogs in northern Minnesota which are built up on flat surfaces chiefly from the remains of a single plant species.

The commonest plant remains found in the peat deposits which have originated in this manner are those of sphagnum, sedges and grasses. These are never mixed in the same layers of peat. Oftentimes the peat in a given bog will consist almost entirely of sphagnum, especially in the coniferous forest region. In the prairie region, the peat in these built-up deposits consists almost entirely of sedges and grasses. Where both sphagnum and sedges occur in the same deposit the sphagnum always is found in layers overlying the sedge peat.

The plants now found growing on these built-up bogs are, in many cases, the same as those from which the peat in the deposit has formed. In other instances the bogs have passed into a more advanced stage, and plant associations of heaths and sphagnum, or tamarack and spruce are found growing on peat consisting mostly of sedge remains or layers of sedge peat, covered with

sphagnum peat. The largest built-up bogs in the coniferous forest regions of the north are now in the tamarack-spruce stage, or bog-heath-sphagnum stage. These built-up deposits, when in such advanced stages of development, cannot be distinguished from the filled-lake bogs by any surface indications. Their true nature can only be ascertained by the study of the plant remains in the peat, and by a careful determination of the character and topography of the bottom of the bog by means of numerous test holes.

As already pointed out, under certain conditions of water level, peat may be built up layer by layer on top of filled-lake deposits. These bogs may also show the same plant associations as those now growing on the surface and hence it is usually impossible to determine the history of any given bog in the northern part of North America from a casual inspection of the vegetation growing on the surface.

#### PHYSICAL AND CHEMICAL PROPERTIES OF MINNESOTA PEAT.

##### *Color.*

The prevailing color of Minnesota peat is brown. Dark brown predominates, while light or yellowish-brown is a common shade. The pond peat, composed of aquatic plants, is nearly always greenish, varying from yellowish-green to greenish-brown. In a few deep bogs, peat of a straw-yellow color was found near the bottom. All the peat, regardless of the color, turns a darker shade within a few minutes after being dug and exposed to the air. Black peat occurs in the bottom layers of some of the deposits, but only a few such instances were noted.

##### *Texture.*

The texture of the peat also varies greatly, and is dependent upon (1) the type of plants composing the peat; (2) the manner in which the deposit was formed; and (3) the degree of decomposition. The commonest texture in the Minnesota deposits is fibrous or mossy. The upper layers of all the deposits are dis-

tinctly fibrous. In some of the open sedge bogs the upper portion of the peat is spongy. The sphagnum peat is mossy. This fibrous or mossy peat extends downward for variable distances depending upon the types of plants composing the middle and lower layers of the deposits, and upon the amount of decomposition which has taken place. The bottom layers are often well decomposed, and the fibrous texture is destroyed.

*Chemical Composition and Fuel Value.*

The following table of analyses shows the chemical composition and fuel value of 29 samples of typical peat from northern

ANALYSES OF SOME PEAT SAMPLES FROM MINNESOTA.

(Analyses by United States Bureau of Mines.)

Locality, County.	Analysis No.	Locality No.	Moisture as Received.	Proximate.			Ultimate.					Thermal Value B. T. U.	
				Vola- tile Matter.	Fixed Car- bon.	Ash.	Sul- phur.	Ni- tro- gen.	Hy- dro- gen.	Car- bon.	Oxy- gen.	Moist- ure.	Moisture and Ash Free.
St. Louis..	188	10	14.33	59.82	26.66	13.52	.29	1.63				7,862	9,091
"	189	11	12.65	60.82	26.01	13.17	.29	2.16				8,490	9,778
"	190	12	14.05	60.71	20.85	18.44	.52	1.65				7,466	9,154
"	191	18	14.58	65.73	23.97	10.30	.28	2.62				8,950	9,978
"	192	19	26.43	62.62	20.69	16.69	.24	2.26				8,289	9,949
"	193	20	14.53	64.96	25.04	10.00	.25	2.49	4.83	53.88	28.55	8,896	9,884
"	194	21	13.45	67.51	24.40	8.09	.24	2.58	5.23	53.24	30.62	9,153	9,959
"	195	21a	40.35	69.66	20.37	9.97	.34	2.35				8,899	9,884
"	196	22	12.48	66.64	24.79	8.57	.26	2.38	5.29	52.91	30.59	9,149	10,006
"	197	23	13.38	65.65	24.16	10.19	.18	1.93				8,698	9,685
"	198	24	24.00	66.22	23.45	10.33	.14	1.76				8,930	9,959
"	199	25	20.10	61.95	24.62	13.43	.29	1.68				8,150	9,415
"	200	26	16.73	61.63	22.94	15.43	.31	1.95				8,098	9,575
"	201	27	12.80	61.50	22.41	16.09	.31	2.68				8,403	10,014
"	202	28	14.20	64.25	23.77	11.98	.31	2.67				8,902	10,114
"	203	29	36.60	62.98	18.91	18.11	.25	2.03				7,953	9,771
"	204	30	9.83	63.62	24.07	12.31	.30	2.64				8,762	9,992
"	205	31	11.03	66.54	24.88	8.58	.26	2.69	5.33	52.41	30.73	9,056	9,906
"	206	32	10.78	74.17	22.60	13.23	.21	2.68				8,637	9,955
"	207	33	13.55	62.06	22.87	15.07	.22	2.73				8,351	9,832
"	208	34	16.83	63.91	24.01	12.08	.37	2.56				8,649	9,837
"	209	35	16.53	60.98	24.28	14.74	.29	2.34				8,409	9,863
"	210	36	40.35	65.72	21.04	13.24	.28	2.43				8,620	9,936
"	211	37	12.60	68.97	23.84	7.18	.21	2.17	5.42	52.93	32.08	9,265	9,983
"	212	38	10.20	63.81	27.92	8.27	.27	1.15	4.74	52.43	33.14	8,849	9,646
"	213	39	12.10	66.15	25.20	8.65	.23	1.75	5.12	53.44	58.50	9,146	10,012
"	214	40	11.63	60.15	23.84	16.01	.65	2.32				8,240	9,188
"	215	41	9.25	58.90	17.13	23.97	.37	2.62				7,949	10,456
"	216	41a	9.83	67.26	22.67	10.07	.40	1.80	5.25	52.17	30.31	9,057	10,072

Minnesota. The most noteworthy features of the analyses are the high average nitrogen content of the peat, and the comparatively low ash content, both of which indicate peat of excellent quality for fuel. The composition and fuel values compare favorably with those of peat from other regions both in the United States and in Europe.

*Distribution and Quantity of Peat in Minnesota.*

The peat deposits of Minnesota fall into three more or less distinct groups: (1) in the northern part of the state, the so-called "muskeg swamps," occur chiefly in Beltrami, Koochiching, St. Louis, Itasca, Roseau, Aitkin, Crow Wing, Cass, and Clearwater counties; (2) in the central part of the state, the largest and best deposits are in Anoka, Ramsey, Wright, Hennepin, Stearns, Sherburne, Isanti, Washington, Chisago, Millelacs, and Douglas counties; and (3) in southern Minnesota, principally in Blue Earth, Nicollet, Le Sueur, Rice, Scott, Carver, Dakota, Steele, Freeborn, and Waseca counties.

The only areas in Minnesota which do not contain peat deposits are: (1) the "driftless area" in the extreme southeastern part of the state; (2) an area in the Red River Valley in the extreme northwestern corner; and (3) a narrow strip along the boundary between Minnesota and North and South Dakota, on the extreme western edge of the state.

From the investigations made by the writer for the Minnesota Geological Survey, it is estimated that Minnesota had originally about 7,000,000 acres of peat land containing peat deposits varying in thickness from a few inches to 30 feet or more. Of this great area, about 5,217,000 acres are covered with peat at least 5 feet thick (the minimum workable depth). The total quantity of peat available for machine peat fuel of good quality in Minnesota, occurring in deposits 5 feet or more thick, estimated on a basis of 200 tons of air-dry machine peat per acre-foot of peat, is approximately 6,835,300,000 short tons.

If this peat were converted into machine peat bricks and sold at \$3.00 per ton, it would have a value of \$20,505,900,000.

The largest and best peat fuel deposits in Minnesota occur in St. Louis, Koochiching, Beltrami, Itasca, Aitkin, Carlton, and Roseau counties—all in the northern part of the state. There are many hundreds of smaller bogs scattered throughout nearly every county in central and northern Minnesota, most of which contain good fuel peat.

While most of the peat deposits are now too remote from railroads to offer immediate commercial possibilities, there are nevertheless hundreds of thousands of acres of peat fuel deposits of the highest quality which are crossed by railroads.

#### POSSIBLE USES OF MINNESOTA PEAT.

##### *Peat Fuel.*

One of the most important problems in northern Minnesota at the present time concerns the most profitable commercial use that can be made of the peat deposits of that region. It seems probable that the manufacture of power in peat producer-gas plants will soon be attempted, and there seems to be an unusual opportunity in Minnesota for success in that field, especially near the iron-mining districts. Such power has been successfully produced in a number of large plants in Europe, and there seems to be no reason why their success cannot be duplicated here.

There is also an attractive field in Minnesota for the manufacture of *machine peat* for domestic fuel.

Although there are no commercial plants for the manufacture of peat fuel in the United States at the present time, it is probable that the industry will develop in this country within a few years, as it has been developed to a high degree in Europe. A large experimental peat fuel plant was recently operated at Alfred, Ontario, by the Canada Department of Mines,<sup>8</sup> and after the manufacture of machine peat was proved to be commercially successful, the plant was taken over by private interests. Plate

<sup>8</sup> For descriptions of various types of peat machines, and peat manufacturing processes, see Bulletin 16, U. S. Bureau of Mines, and Publications 151, 154, 266, 299, Mines Branch, Canada Department of Mines.

XXXIV. shows two views of the Ontario peat fuel plant. The peat used at the Ontario plant was identical in quality with that found at numerous localities in northern Minnesota.

Modern peat fuel is made by special machinery and the product, which is put on the market in the shape of blocks, or bricks, similar to stove wood in size, shape and weight, is called *machine peat*. This is the type of peat fuel which has proved to be a commercial success in Europe and in Canada, and which will probably form the basis of any peat fuel industry which may develop in this country in the future.

Numerous plants have been built to manufacture peat briquettes but none of these attempts have as yet proved to be commercially successful. The chief difficulty to be overcome seems to be the high cost of eliminating the moisture from the raw peat by any method of artificial drying. Machine peat is dried in the sun.

#### *By-Products from Manufacture of Producer-Gas.*

The principal by-product which can be obtained from the manufacture of producer-gas is ammonium sulphate  $(\text{NH}_4)_2\text{SO}_4$ , which, because of its high nitrogen content, is in great demand as a fertilizer. Theoretically, 1 short ton of dry peat containing 1 per cent. nitrogen will yield 94 pounds of ammonium sulphate. In the European plants the recovery is about 75 per cent., i. e., approximately 70 pounds of ammonium sulphate are produced per short ton of peat burned, calculated on a moisture-free basis.

#### *Agricultural Uses of Peat.*

The possibility of using the large tracts of shallow peat land in northern Minnesota for agriculture is of the greatest importance, and the industrial future of several entire counties in the northern part of the state depends to a large extent upon the uses which can be made of the peat deposits there. Already a large acreage of peat land is under cultivation. The results of experiments made in this country and at European peat experiment stations show that peat soils will produce satisfactory

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EXPLANATION TO PLATE XXXI.

A. Looking along drainage ditch through a typical tamarack swamp of northern Minnesota. Peat is two to seven feet thick. Note plat spread out for road-bed.

B. View along newly constructed road through dense black spruce swamp, northern Minnesota. Peat is about five feet thick.



A



B





A



B

## *THE PEAT DEPOSITS OF MINNESOTA.*

### EXPLANATION TO PLATE XXXII.

A. Peat deposit of the filled lake type, northern Minnesota. Note the old shore line. Peat is four to ten feet thick.

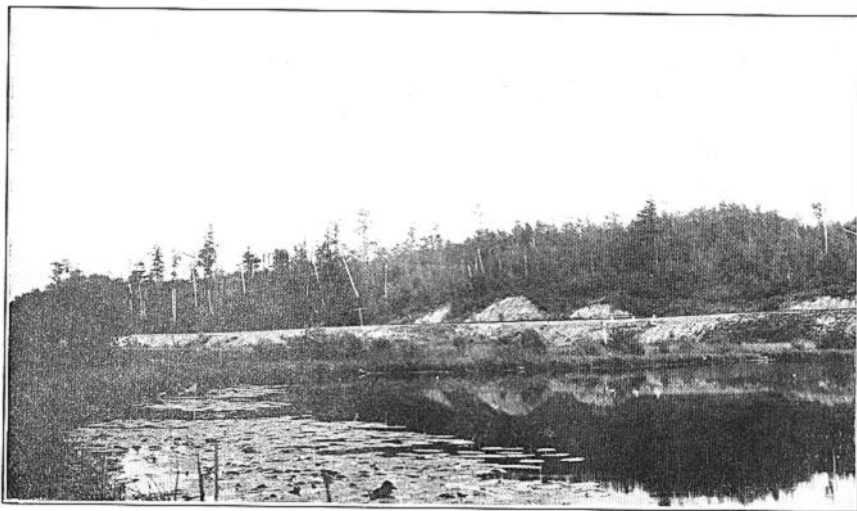
B. View along drainage ditch through big open peat bog in northern Minnesota with tamarack zone in the distance. Note the peat on the spoil bank of the ditch, which is levelled off for a wagon road. Peat is seven to twenty feet thick.

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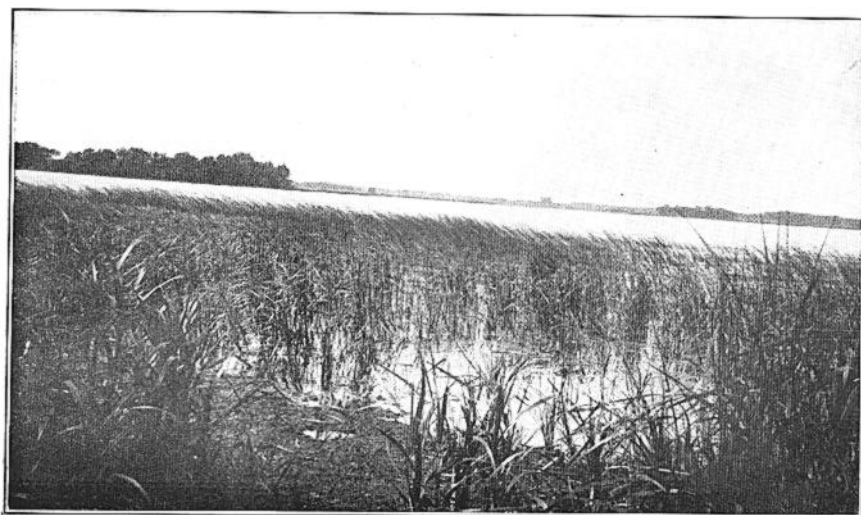
EXPLANATION TO PLATE XXXIII.

A. Pond-lily and sedge zones around peat-forming lake in Itasca County, Minnesota.

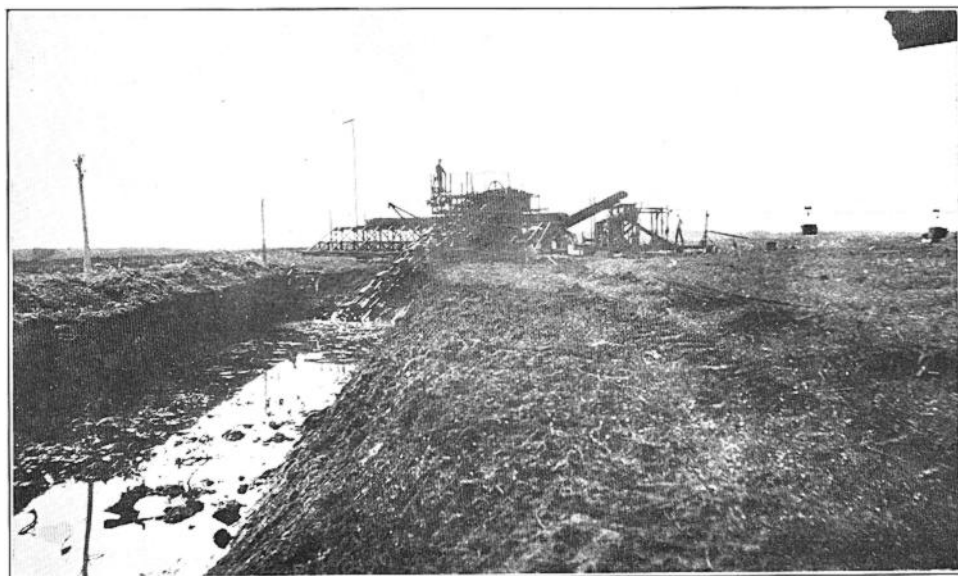
B. Zones of bulrushes and giant sedges around border of a peat-forming lake in southern Minnesota. Note floating mat of vegetation in immediate foreground.



A



B



A



B

## *THE PEAT DEPOSITS OF MINNESOTA*

### EXPLANATION TO PLATE XXXIV.

A. Peat machine (Moore System) in operation at Alfred, Ontario. (Photo by E. V. Moore.)

B. View showing method of spreading and drying machine peat on the bog (Moore System) at the Alfred plant, Alfred, Ontario. The row on the left has been cross cut into blocks, while the row in the center has just been spread. Note peat machine in the distance and trolley for operating spreader to the right. (Photo by E. V. Moore.)

crops of forage plants, small grains, and all ordinary vegetables except asparagus, with proper cultivation, and fertilization. There are, however, certain limitations upon the profitable cultivation of peat bogs.<sup>9</sup> These are: (1) drainage, (2) depth and character of peat, (3) climate, (4) transportation facilities, and (5) expense of marketing the products.

#### *Other Uses.*

The possibility of using peat in the iron-ore industry of Minnesota has been suggested by Professor Peter Christianson, of the Minnesota School of Mines. The possible applications, as suggested by Professor Christianson, are: (1) the use of peat for power; (2) the use of peat for heating operations in drying, roasting, sintering or calcining; (3) the use of peat as a binder in ore briquetting; and (4) the possible use of peat coke or charcoal in smelting.

Peat is extensively used in the United States as a fertilizer filler, in which capacity it is said to improve the fertilizer both chemically and mechanically. It is also used in this country to a considerable extent for stable litter and packing material. The fibrous and mossy peats of Minnesota would be especially suitable for such uses. Other uses for peat are: for paper stock, woven fabrics, ammonium compounds, artificial wood, manufacture of nitrate, dye stuffs, materials for tanning, and sanitary and medicinal uses.

<sup>9</sup> "Limitations on the Cultivation of Peat Lands in Minnesota," F. J. Always, *Journal American Peat Society*, April, 1916, p. 65.