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THE PEAT DEPOSITS OF MINNESOTA

BY

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THE PEAT DEPOSITS OF MINNESOTA

By E. K. Soper

INTRODUCTION

This bulletin outlines and describes the peat deposits of Minnesota and indicates methods by which they may be utilized for fuel and other purposes. It contains also a discussion of certain areas of peat land in various parts of the state, and purposes for which they are best adapted, whether for agriculture or for the manufacture of peat products.

The peat deposits of Minnesota are probably greater than those of any other state in the Union, the quantity of peat being sufficient to make more than six billion tons of good peat fuel. Because of the enormous areas of many of the peat deposits, it was soon realized that any detailed testing of the bogs could be done only on certain selected areas which seem to be especially well situated for development. Such a detailed testing of some of the largest deposits would require years to complete, and in view of the constantly increasing demand in Minnesota for a report on the peat, or muskeg lands of the state, and especially a demand for knowledge as to the agricultural possibilities of these areas, it was decided to examine as many localities as possible and to publish a report of a more general nature which would include descriptions of most of the larger muskegs and peat deposits. Enough soundings were made to determine whether the land should be classified as easily reclaimable, or as better adapted to the manufacture of peat fuel or other peat products. During the two seasons of field work every county in Minnesota was visited and detailed examinations were made in every county which contains peat. In addition to the data thus collected, a large amount of valuable data, including thousands of soundings, has been supplied by the engineers engaged in the various public and private projects for draining the great swamps of northern Minnesota.

The various localities which were visited were given location numbers and each bog is described in detail, in the discussion by counties, in Part III of this report. It has been impossible to state the total areas of all the individual localities, for most of these are not independent bogs, but represent localities in very large swamps, one of which covers more than 1,000 square miles, and many others contain areas of 100 square miles or more. The character, composition, and depth of the peat, as well as the vegetation growing on the surface of the bog, vary at different places throughout these immense swamps, and so it has been necessary to visit and examine many points in each of the larger deposits. The total area of peat land in each of the northern counties has been estimated, and where small bogs, which are complete units, were examined, an estimate is given of the area of the deposit, and of the number of tons of machine peat available.

It is not intended that this report shall supply all of the detailed data necessary for the establishment and operation of a peat fuel plant at any given locality, for such information could only be obtained by a large number of test holes, systematically located, and spaced at short intervals, over each small area under consideration. Such a detailed study of all the bogs which contain good fuel peat would require years to complete.

The field studies of the Minnesota bogs were made by the writer during the summers of 1914 and 1915. In the gathering of data for this report, the writer was assisted in the field, during the summer and fall of 1915, by Percy G. Cowin. Acknowledgments are due to the late Dr. C. A. Davis, of the United States Bureau of Mines, and Dr. W. H. Emmons, director of the Minnesota Geological Survey, for much valuable assistance and criticism; to Dr. F. J. Alway, of the Division of Soils, Minnesota Agricultural Experiment Station, for contributions on the agricultural possibilities of Minnesota peat lands; to Professor H. F. Bergman, of the Department of Botany, University of Minnesota, for contributions on the plant life of the Minnesota peat bogs; and to Professor Peter Christianson, Minnesota School of Mines, for contributions on the possibilities of the utilization of peat in the smelting of iron ores. Thanks are also due to Professor Frank Leverett, and Professor F. W. Sardeson, whose work on the surface formations of northern Minnesota has been the source of valuable data. Credit is given to the engineers in charge of the drainage of state lands in northern Minnesota; and especially to Mr. E. W. Kibbey for the map of peat bogs in portions of Koochiching County; to Mr. W. M. Everts for soundings and profiles of peat bogs in Beltrami County; and to Mr. O. L. Dent for valuable assistance rendered in the field, and to many others whose assistance has greatly aided this investigation.

PART I

THE ORIGIN, OCCURRENCE, AND USES OF PEAT

THE ORIGIN OF PEAT

DEFINITION OF PEAT AND MUCK

When vegetable matter undergoes decay the amount of decomposition depends upon the conditions that prevail. Decay may be complete or only partial. Peat is partly decomposed and disintegrated vegetable matter which has undergone both chemical and mechanical change, but which still contains most of the carbon of the original vegetable matter, and in which the vegetable structure may readily be seen. It often contains well preserved plant remains such as leaves, roots, stems, and seeds.[1] Peat deposits are accumulations of such vegetable remains as have been prevented from complete decomposition. They may form in any place where there is sufficient vegetation and where other conditions are such as to prevent or delay its decay.

Muck is a term used to designate a very impure peat or peat soil, in which the amount of inorganic mineral matter is approximately equal to, or greater than, the amount of combustible organic matter. There is no sharp line of demarkation between muck and peat. A deposit containing more than 25 per cent inorganic mineral matter and less than 75 per cent of vegetable matter, may be called either impure peat, peaty soil, or muck. The term muck has been loosely used, but it is becoming more and more restricted to designate deposits in which the per cent of noncombustible inorganic mineral matter is so great as to give to the material more of the properties of a heavy black soil than of peat.

Defined from the view-point of utilization, peat may be a fuel, or a soil, or merely partly decomposed vegetable matter of little value for either fuel or soil depending upon its occurrence and physical and chemical properties.[2]

COMPOSITION OF VEGETABLE MATTER

Vegetable matter is made up of numerous and complex organic compounds. It consists chiefly of three or four elements: carbon, oxygen, hydrogen, and nitrogen, with which some inorganic matter is always associated and which forms the ash when combustion takes place. The two principal compounds composing most vegetable matter are cellulose,

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[1] Charles A. Davis, The Uses of Peat for Fuel and Other Purposes. *Bulletin* 16. U. S. Bureau of Mines p. 8. 1911.

——— Peat: Essays on Its Origin, Uses, and Distribution in Michigan. Geol. Survey of Mich. *An. Report* p. 107. 1906.

[2] Alfred Dachnowski, Peat Deposits of Ohio. Geological Survey of Ohio, 4th Series. *Bulletin* 16 p. 17. 1912.

or vegetable fibre ($C_6H_{10}O_5$), and lignin, or woody fibre ($C_{35}H_{24}O_{20}$). These substances form the chief part of the wood, leaves, stems, and roots of plants.

The chief fuel element in all fuels is uncombined carbon, or carbon partly combined with oxygen. When wood or vegetable matter is transformed to peat, and from peat to lignite and coal, the cellulose, lignin, and other compounds break down and liberate a part of their carbon which goes to increase the amount of free, or fixed, carbon in the resulting fuel, by which its value is measured. This breaking down of cellulose and lignin is furthered by the complexity of their composition which renders them unstable.[3]

DECAY OF VEGETABLE MATTER

When vegetable matter is exposed to the air in the presence of moisture, it rapidly decomposes and finally disappears completely. A part of it is volatilized and escapes into the atmosphere as gas, and the residue joins the mantle of decomposed mineral matter at the surface of the earth and aids in forming soil. It was formerly believed that this decomposition was a simple form of oxidation, comparable in every respect to the burning of vegetable matter. Even to-day this explanation is not infrequently made. But this is not the case. The decay of vegetable matter is a series of complicated changes brought about largely by the growth and development of living organisms in the decaying matter.

These organisms which accomplish the decay of vegetable matter are both plants and animals, but chiefly plants,—fungi and bacteria. They use a part of the vegetable tissue for their own growth and thus break it down. In certain more or less definite proportions they require both water and air. Moreover, they require a favorable temperature for their development. When the manner of growth and development of these organisms, and the effects they produce, are understood, the explanation of the absence of peat in some localities, and its presence in others, becomes clearly apparent. The many variations in the physical and chemical composition and the degree of decomposition of peat deposits are also seen to be due to the influence of these organisms. In the presence of sufficient air and moisture in the proper proportions the rate of action of these decomposing agents is so rapid that peat deposits do not form. Under unfavorable conditions, i.e., absence of sufficient air or excess of water, the action is very slow and vegetable remains may accumulate and large peat deposits may form. When organisms aiding decomposition are completely excluded from water or air, there may

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[3] Charles A. Davis, Peat: Essays on Its Origin, Uses and Distribution in Michigan. Geol. Survey of Mich. *An. Report* pp. 105-6. 1906.

A. SMALL MUSKEG BOG OF THE FILLED-LAKE TYPE OCCUPYING A DEEP BASIN BETWEEN TWO MORAINIC RIDGES. ITASCA COUNTY

B. OPEN WILD RICE MARSH OCCUPYING DEPRESSION IN UNDULATING DRIFT SURFACE NEAR FEDERAL DAM, CASS COUNTY

be very little change in the accumulating vegetable matter. Under such conditions wood has been known to remain hard and undecayed for thousands of years. The principal products of decay of vegetable matter are carbon dioxide (CO_2), ammonia (NH_3), and water (H_2O). These substances pass off as gases into the atmosphere. The carbon remains, for the most part, in the residue; thus the more decomposition vegetable matter has undergone, up to a certain degree, the greater the amount of fixed carbon which remains in the peat, and hence the higher its fuel value.

These same bacteria are present in all soils and it is largely to their action that soils owe their fertility. They are most numerous near the surface and extend downward to a depth where the amount of air is so small, or the temperature is such, that they can not live. According to Dachnowski,[4] bacteria are concerned with almost every important phase of soil in its relation to life.

The effect of bacteria on peat and dead vegetable matter is discussed in the section of this report devoted to the agricultural uses of peat for the production of nitrates.[5] (See p. 93.)

GENERAL CONDITIONS UNDER WHICH PEAT FORMS

The most important factors in the origin of peat are (1) climatic, (2) topographic, and (3) geologic. The amount and type of vegetation of a given region will be controlled by climate, topography, and geology. 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. There are no large peat bogs in rugged or mountain regions. A few small deposits occupying glacial pockets and basins occur in mountains, and peat bogs occur in Ireland on rather steep hill slopes. Low wet areas are called bogs, marshes, and swamps.

CLASSIFICATION OF FRESH WATER SWAMPS

Bogs.—A bog is an almost flat, fairly open area, relatively free from trees, except small scattered tamarack or black spruce, and covered chiefly with moss (usually sphagnum) and heath shrubs. To this class belong most of the so-called "muskegs" of northern Minnesota, Wisconsin, Michigan, and eastern Canada. Plate V, A, shows a typical "muskeg," or bog.

Marshes.—A marsh is an open, flat, wet area, usually covered by a thick growth of sedges and grasses, often with cattails, bulrushes and reed-grass, and some show small mosses and ferns. They seldom

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[4] Alfred Dachnowski, *op. cit.* p. 23.

[5] W. B. Bottomley, The Bacterial Treatment of Peat. *Journal Royal Society of Arts*, 62:373. March, 1914. *Journal American Peat Society* 7:70. 1914.

contain sphagnum moss or heath shrubs, and are treeless. Such marshes are usually found adjoining lakes or rivers, and are typically developed in Minnesota along the Mississippi River and its larger tributaries and around many lakes in the central part of the state. They attain their best development south of the latitudes of the big sphagnum, tamarack, and spruce muskegs of the northern part of the state. The soil, or peat, is much firmer than that of the typical moss bogs, although it is always saturated with water and frequently flooded. Plate VII, B, on p. 43 shows a typical peat marsh.

Swamps.—The chief vegetation of swamps consists of trees and shrubs although the ground may be covered by a thick mat of sphagnum moss as it is in most of the northern Minnesota swamps. The chief distinction between swamps and bogs in the north is the abundance of trees and shrubs in the former, and the fact that in swamps the soil, or peat, is firmer. The prevailing trees in the swamps of the northern United States are tamarack, black spruce, and swamp cedar. Both swamps and bogs are called "muskegs" in northern Minnesota, Wisconsin, Michigan, and Canada, and it is often difficult to classify a given area because the two types grade into each other. Many large tamarack or spruce swamps contain smaller open areas within them, which are typical sphagnum bogs. The distinction between swamps and bogs is therefore somewhat arbitrary in many cases. Where the term "muskeg" is used to describe a wet area, the word swamp or bog added to it would convey a more exact impression of the type of land. A muskeg bog is an area covered with sphagnum and low heath shrubs, with relatively few scattered, scrub tamaracks, or spruces, or both; while a muskeg swamp is an area covered with a more or less dense growth of tamarack, spruce, or cedar timber, or mixtures of these, in addition to the sphagnum and heath shrubs. These distinctions are made in this paper. Plate VIII, A, opposite page 44, shows a typical muskeg swamp of northern Minnesota.

CLIMATIC INFLUENCES

The most important climatic influences in peat formation are (1) regular and abundant rainfall, and (2) high humidity of the air.[6] A cool or temperate climate is favorable, but this is not essential, for peat deposits are known in warm climates such as that of Florida. There is, however, very little peat known to exist in the tropics, and the peat that is formed in warm regions has formed under conditions that were otherwise exceptionally favorable. Most of the peat in the United States lies north of 40° N. latitude and east of the Dakotas. The largest

[6] Charles A. Davis, The Uses of Peat. *Bulletin* 16. U. S. Bureau of Mines p. 16. 1911.

and deepest deposits in North America occur within this area, along the Canadian boundary, on both sides of the line.

In Europe also, the extensive peat deposits are mostly in the northern countries, where the climate is similar to that of northern North America.

Many thousand acres of the North German Plain are underlain by deposits of peat. According to Ries[7] there are 1,576,000 acres of flat bog, and 1,254,000 acres of mountain bog in Ireland alone. Russia is said to have 67,000 square miles of peat land, and there are several million acres in Norway and Sweden, while extensive deposits are not lacking in France and Holland.

On the other hand, in the far north, where the summers are short, and the winters long and extremely cold, little peat accumulates. Under such conditions, the short growing season results in such a sparse growth of vegetation in any single year, that there is insufficient material to form extensive peat deposits.[8]

EFFECTS OF TOPOGRAPHY

The influence of the topography of the land surface upon the formation of peat is also important. As already stated, peat deposits usually form in depressions, such as lakes, ponds, and basins, or on low, flat, undrained areas, which are kept constantly wet or moist. Just as the climate controls the amount of peat which can form in a given region, so the topography controls the distribution of the peat. Even if the climatic conditions favorable to peat formation prevail in a region, peat can not form unless the topography of the surface is such that suitable places exist for its accumulation.

In most of the regions of the world where peat is accumulating to any extent, the land surface is low and flat. In North America, glaciation has affected the land surface, and drainage has been greatly retarded, thus keeping large areas constantly wet. The principal topographic conditions favoring peat formation are those of a region of slight stream erosion and sedimentation.[9] Such a topography is either very young or very old.

While most peat bogs occur on flat areas, these surfaces are not necessarily level. In humid regions, with cool temperate climates, swamps form on surfaces having a gradient of five feet per mile, and in some Minnesota bogs the gradient is as much as twelve to fifteen feet per mile.

Areas in southern latitudes must be flatter than northern areas, where both regions have an equal rainfall, in order to ensure an accumula-

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[7] H. Ries, Twenty-first Report of the New York State Geologist 1901 p. 58-9. 1903.

[8] N. S. Shaler, U.S.G.S. *Sixteenth Annual Report* Part IV. Origin, Distribution, and Commercial Value of Peat Deposits p. 310. 1895.

[9] Alfred Dachnowski, *op. cit.* p. 21.

tion of peat, because the vegetable matter is more quickly oxidized in the hot season. In arid regions, gradients as low as five feet per mile would not permit peat to form.

Where peat accumulates in basins or depressions, its formation is independent of the gradient of the general land surface of the surrounding region. Most of the very deep peat deposits of the world have accumulated in lakes. An area which contains a large number of undrained basins, depressions, or hollows favors thick accumulation of peat. Such a topography results from glaciation, and is especially characteristic of morainic regions. In North America all of the deepest peat bogs occupy depressions in glacial drift. Topography not only controls the horizontal area of swamps, but it also controls their vertical limits.

EFFECT OF GEOLOGY

The geology of a region is indirectly concerned in peat formation through the geologic processes which have produced the topographic forms of land surface upon which peat has accumulated. The most important results have been accomplished through the action of ice as a geologic agent. Both erosion and deposition have contributed to the molding of the topographic forms of surface favorable to the development of swamps and lakes.

The effect of rocks exposed at the surface, upon the development of peat bogs is important in some localities. A great diversity of rock outcrops results in greater irregularity of topography because it influences erosion and glaciation. The effect of the character of the glacial drift, or soil, upon the formation of peat is also of some importance. Nearly all peat soils are "acid" soils. Sphagnum moss, the most important peat-forming plant in North America, does not grow well in a soil rich in lime, or on a bog where the water contains much lime in solution. Consequently, areas covered by very limy soils are not favorable for the accumulation of large deposits of sphagnum peat.

Glacial till, or loose soil, more often makes streams muddy than firm clay or rock. Hence, in regions of loose soil and till where peat bogs occur along stream valleys, and where the bog is subject to overflow at periods of high water, the peat usually contains considerable silt or sand, which greatly increases its ash content, and renders it unfit for fuel.

In some parts of the world, extensive peat bogs have developed because of the formation of marshes which resulted from the sinking of the land by diastrophic movements since glacial time. In the United States, examples of peat bogs which are the result of such diastrophic movements occur in Massachusetts, on the coasts of New Jersey, Connecticut, and Florida, and in the northeastern part of the Great Lakes region.[10]

GLACIAL INFLUENCES

The peat in the northern part of the United States and in Canada, as well as great areas in Europe, owes its origin directly or indirectly to the influence of glaciation. Without the invasion of northern North America by the Continental Ice Sheet, it is probable that not all of the conditions would exist which now seem essential to the accumulation of large deposits of peat in this latitude and climate. The only peat deposits in North America which do not owe their origin to the glaciation of the region are comparatively small bogs along the Atlantic coast from Maine to Florida, and the tule marshes of California.

Not only are most of the peat bogs of North America due to glaciation, but it is probable that nearly half of the swamp areas in North America which are redeemable to agriculture are to be attributed to the disturbance of the drainage produced by the last glacial period.[11]

The lakes which are now filled with peat were all formed at the close of the Glacial Period. Over much of the glaciated area already described as containing most of the peat in North America, the land is dotted with thousands of glacial lakes, small and large. Many of these are filled with peat; others have almost disappeared because of peat filling, while in many others peat is still slowly accumulating and the process may now be observed.

All peat has not accumulated in lakes and ponds. Some of the largest bogs in the world, including hundreds of square miles of bogs in North America, have been built up on marshy, flat, undrained surfaces. The peat has not formed by the accumulation of plant remains under water, but on the surface of the land. This is shown by the existence of large peat beds which do not contain any aquatic plant remains. These peat deposits, however, all occur (in North America) in glaciated regions, and the peat owes its origin to the effects of glaciation of the land surface, which changed or hindered the drainage, and rendered the land swampy.

The various ways in which glaciation has altered the surface of the land—gouging out basins, and damming up drainage channels, thus producing topographic conditions favorable to peat accumulation—are discussed in detail under the descriptions of the Minnesota bogs in the following pages.

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[10] N. S. Shaler, *op. cit.* pp. 312-13.

[11] N. S. Shaler, Account of the Fresh Water Morasses of the United States. U. S. Geological Survey. *10th Annual Report* p. 303. 1888.

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 deposits are different, especially in the earlier stages of development of the bogs. The plant associations which are characteristic of the two types of bogs are treated below.

PLANT DEPOSITS IN LAKES AND PONDS

Peat deposits which accumulate in lakes or ponds in coniferous forest regions go through the following developmental stages, if not arrested through the influence of some external agency.[12]

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

In the deciduous forest regions the peat bogs go through essentially the same stages until the lake is filled with peat, when the 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 accumulation, the swamp vegetation, consisting chiefly of sedges, reed-grasses, etc., is replaced by the typical prairie grasses, such as bluestem, Indian grass, and porcupine grass.

In the process of peat formation by the filling of lakes, the first plants to become established are those which grow under water. Among the lowest types, algae and certain mosses, and a few other spore-bearing plants grow entirely beneath the surface of the water. Of the aquatic seed plants which are also among the first types to appear in lakes and ponds, stoneworts, waterweed, pondweed and water-lily predominate. The water-lilies intercept the sunlight falling upon their leaves and prevent the growth of plants which thrive beneath the surface of the water, and thus a distinct zone of water-lilies is often developed around the borders of lakes.

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[12] H. F. Bergman, Department of Botany, University of Minnesota. Unpublished manuscript.

Farther shoreward from the water-lily zone, in water of shallower depth, rushes, reeds, cattails, and wild rice appear. These do not always occur together; sometimes only a single species is represented, but more often two or three are present. As the lake gradually fills up, these plants advance farther toward the center, and under certain conditions a lake may thus become completely filled with this association of plants, especially if the water is shallow and the bottom flat.

At the margin of lakes and ponds, and shoreward from the rushes, cattails, reeds, or wild rice, there is usually a well defined zone of sedges, of which various species of carex are most common. This sedge zone extends from the water's edge inland for a variable distance, depending upon what stage of filling the lake represents. The sedges usually grow out from shore, in water to a depth of several feet. Gradually, as the lake fills up, these plants may take complete possession of the area, crowding out the species of the earlier stages. Associated with the sedges are numerous secondary species, some of which may attain a prominent development. The sedges, because of their strong, tough, branching, underground stems and roots, often take complete possession of the bottom around the shores, and gradually form a firm, tough turf. As this turf grows in thickness and strength by constant additions to its mass, it may finally become so strong and buoyant that it builds a floating mat or shelf around the margins of the lake. This is called the "sedge mat" and is typical of this stage in the process of the filling of many of the peat-forming lakes throughout the world. In some cases, where lakes are in the last stages of filling, this sedge mat completely covers the remaining surface of the water. Upon this sedge mat other plants take root and the peat is thus built up as a thick mat floating on the remnants of the lake. Several such deposits were found by the writer in northern Minnesota. The floating peat mats varied in thickness from 1 to 15 feet, and the underlying water varied in depth from 6 to 18 feet in the different bogs tested.

The plants which first appear upon the sedge mat consist of certain herbs and shrubs. The herbs can grow on the hummocks of very thin mats saturated with water. Farther toward shore, on the firmer and drier parts of the mat, the shrubs first appear. These are usually heaths, of which leather-leaf (*Cassandra*), bog rosemary (*Andromeda*), and Labrador tea are commonest. Frequently small willows appear at this stage in the bog's development.

With the bog-heaths or immediately following them, sphagnum, or peat moss, appears. When this plant is once established it grows rapidly. The surface of the bog is quickly raised by the continual growing of the sphagnum at the top and its dying below. Sphagnum is the most rapid peat former in the Minnesota bogs. The plant is limited in its growth by the height to which the water will rise through the mass of interlaced roots and stems above the general water level of the bog. In Minnesota and Michigan[13] this height is about 3 to 3½ feet. If the water level of the bog is raised as the layers of sphagnum peat are built up, which is often the case, the sphagnum may continue to thrive and thus the surface of the bog may be built up for many feet above its original level, i.e., the former water level of the lake. This gradual rising of the water level accounts for the great thickness of almost pure sphagnum peat found in the upper parts of some peat bogs, and explains the origin of built-up peat deposits which are frequently found overlying "filled-in" or pond peat.

The next plant association to make its appearance in existing peat bogs is that of certain coniferous trees, chiefly tamarack and black or swamp spruce. Tamarack is the first to invade the bog-heath and sphagnum zone. The trees first become established on the higher and drier humps of dead sphagnum, or upon mounds of the living moss. In some cases black spruce follows immediately after the tamaracks. In others the tamaracks are alone except for a ragged fringe or zone of spruce trees around the edge of the bog. Rarely, the tamaracks are entirely displaced by the spruce. Many large and excellent examples of spruce swamps were found in northern Minnesota. At first, both the tamaracks and spruce are confined to a zone near shore, but gradually, as the bog is more nearly filled or as the water level is lowered, the trees spread out until they finally cover the entire bog. Most of the big bogs of St. Louis and Koochiching counties and eastern Beltrami County, in northern Minnesota, are now in this latter stage of development.

Finally, as the surface is built up high above the water level, or as the water in the basin is lowered, the history of the bog is completed and peat formation is stopped, and the tamaracks and spruce are displaced by certain deciduous trees.

PLANT DEPOSITS ON FLAT, OR GENTLY SLOPING, WET SURFACES

A swamp represents an arrest in the normal development of the vegetation of a region. Swamps derived from filled lakes, just described, are arrested *primary successions*.[14] 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, which may begin at any point between

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[13] Charles A. Davis, *op. cit.* p. 25.

[14] H. F. Bergman, unpublished manuscript.

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 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. That 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 seldom mixed in the same layers of peat. At many places 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 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, can not be distinguished from the filled-lake bogs from 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 stated, under certain conditions of water level, peat may be built up layer on layer on top of filled-lake deposits. These bogs may also show the same plant associations 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.

THE USES OF PEAT

MANUFACTURE OF MACHINE PEAT FUEL

The old method of making peat fuel, a method still in use in Ireland and some other parts of Europe, was to dig the peat by hand with a slane or spade, and to allow the lumps thus obtained to dry in the sun, after which the product was ready to be burned. Figure 1 shows an

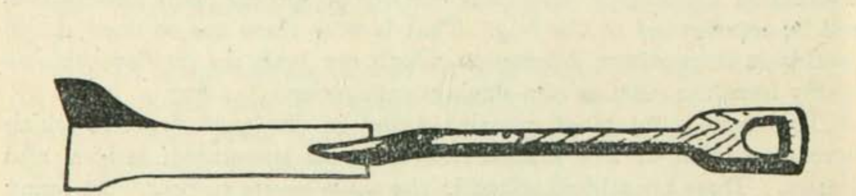
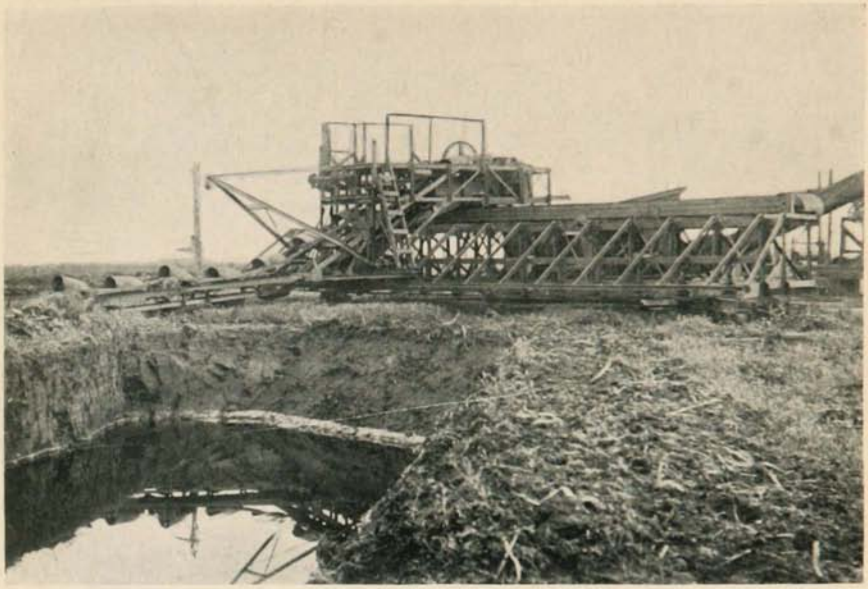


FIGURE 1. UPPER FIGURE, SLANE OF THE EIGHTEENTH CENTURY; LOWER FIGURE, MODERN SLANE

ancient and a modern slane. In Sweden and Holland the peasants sometimes knead the peat into a pulp by treading it either with horses or men, after which the peat pulp is molded by hand into blocks or cakes, and dried in the sun. 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 type of peat fuel has proved a commercial success in Europe and in Canada, and will probably form the basis of any peat fuel industry which may develop in this country.



A. ANREP PEAT MACHINE, WITH MODIFICATIONS BY E. V. MOORE, IN USE ON PEAT BOG AT ALFRED, ONTARIO
PHOTO LOANED BY E. V. MOORE

B. MOORE AUTOMATIC PEAT SPREADER, IN USE AT ALFRED, ONTARIO
PHOTO LOANED BY E. V. MOORE

METHODS OF MANUFACTURE

The chief difficulty to be overcome in the manufacture of peat fuel is the removal of the moisture in the raw peat. The water content is usually close to 85 or 90 per cent of the raw material,—that is, in every 100 pounds of peat dug there are only 10 or 15 pounds of dry peat substance. There are two processes of manufacturing machine peat, the chief points of difference lying in the method of eliminating this high water content. These processes are: (1) the method of removing the moisture by evaporation by the sun and wind; (2) the method of removing most of the moisture by mechanical means, and the use of artificial heat to eliminate the remainder.

The second method, that of artificial drying, has not yet been proved commercially successful. Practically all of the peat fuel produced to-day, in Europe, as well as in America, is manufactured by the air-drying process. This process is merely an improvement on the old method outlined above. The steps in the process are briefly as follows:[15] (1) excavation of the raw peat; (2) pulping or grinding of the excavated peat; (3) transportation of pulped peat to drying field; (4) spreading and cutting the pulped peat into suitable blocks; (5) turning and piling the practically dry peat; (6) transportation to cars or sheds.

The *excavation* of the peat is done either by hand labor or by special excavating machines. In all the larger peat fuel plants, excavating is done by machinery. The excavator may be a bucket dredge or a mechanical digger and elevator. In the latest and most improved types of peat machines the digging and macerating form one continuous operation, all done in a self-propelling portable peat machine.[16] One of these plants is shown on Plate VI. One of the best known peat machines (combination excavator and macerator) is the Anrep peat machine, used at the Alfred, Ontario, and Farnham, Quebec, plants, and in general use in Russia and Sweden. Other successful machines are the Dalberg, widely used in Germany, and to some extent in Italy; and the Strenge, used in Germany. The Moore system is a modification of the Anrep system, and is used at Alfred, Ontario. In 1909, Russia produced 2,080,000 metric tons of machine peat by the Anrep system using over 1,300 machines.

The *pulping* or *maceration* of the peat is accomplished in specially designed macerating mills which operate on much the same principle as the pug-mills in clay-working plants. If the macerated peat is to be cut

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[15] B. F. Haanel, Peat, Lignite, and Coal. *Publication* no. 299. Mines Branch, Canada Department of Mines p. 11. 1914.

[16] For detailed descriptions of the various types of peat machines see *Bulletin* 16, U. S. Bureau of Mines, p. 86-100; *Publications* 151, 154, 266, 299, Mines Branch, Canada Department of Mines; and other publications referred to in the bibliography accompanying this report.

into bricks as it issues from the pulp machine, no water is added to the raw peat. But if the peat is to be poured or spread on the bog, and then cut, sufficient water is added in the pulping process to produce a sludge of the proper consistency, which will pour and spread readily. The type of macerating machine used most commonly to-day consists of a horizontal iron cylinder in which an axial rod rotates swiftly. This axial rod is set with spirally arranged knives and flanges, which act as screws to force the peat forward, and out of the discharge end of the machine, while at the same time they thoroughly mix and macerate it. In some machines another set of stationary knives is placed in the iron wall of the cylinder against which the rotating knives and arms work.

The *transportation* of the pulped or macerated peat from the machine to the drying ground is usually accomplished by a system of portable tracks and tram-cars operated from a drive on the engine which runs the peat machine, or by an aerial cable with traveling buckets. The latter method, known as the Moore system, was devised by Mr. Ernest V. Moore for the peat plant at the Alfred bog, at Alfred, Ontario, and has proved highly satisfactory. This system and others in use at different localities are described in papers referred to in the bibliography on pages 254 to 256, inclusive.

The *spreading* of the pulped peat on the drying ground is usually done with a special spreading machine. There are several types of spreaders, but the best known are the Jakobson spreader and field press, and the Moore automatic peat spreader. The Jakobson spreader consists of a wooden frame built upon two wooden rollers—one in front and one at the rear. A hopper, placed between the rollers, receives the pulped peat from the tram-cars or tram-buckets. The front roller levels the ground as the spreader travels forward. The rear roller regulates the thickness of the peat spread.[17] A series of knives placed at the rear of the machine cuts the spread peat into strips, which are afterwards cross-cut by hand. The machine is operated from a drum attached to the engine of the peat machine.

The Moore automatic peat spreader consists of a bin or box provided with a caterpillar tractor, which is moved over the bog by electric power transmitted by overhead trolley wires to an electric motor placed on the machine. The macerated peat is dumped from the tram-cars into the spreader, where it is forced out of 34 moulding spouts at the rear of the machine by means of screws. The rate of delivery of the peat from the spouts may be controlled by the operator. An automatic cutting device crosscuts the strips of spread peat, thus eliminating the extra labor of crosscutting required in some of the other types of

[17] B. F. Haanel, *op. cit.*

spreaders. Plate VI shows one of the Moore spreaders at work on the Alfred, Ontario, bog.

The turning and stacking of the dried or partially dried peat is done by hand. The partially dried bricks should be turned at least once before stacking. The time required to dry the peat bricks to a water content of 25 per cent (which is the practicable limit in air-drying) will vary necessarily according to the weather. In general, the drying will require at least three weeks, but the best results are obtained when the peat is allowed to dry for the entire summer.

The transportation of the dried bricks from the drying ground to the storage shed, or to cars for shipment, is usually done in small hand cars, which are trammed over a portable track constructed of light rails.

COST OF MANUFACTURING MACHINE PEAT

C. A. Davis[18] estimates the cost of a machine peat plant of 50 tons per day capacity equipped with American machinery for a bog which can not be drained, at $20,000 to $25,000. The cost is made up as follows:

1 dipper dredge	$5,000
6 scows, at $250 each	1,500
1 scow excavator and elevator for unloading scows	1,000
1 factory building and power house	2,000
1 boiler (100 horsepower) and engine (75 horsepower) and installation	1,800
1 heater, pump and fittings	300
1 peat machine and accessories	1,500
Pallets, trucks, and railroad tracks from building to drying grounds	2,500
Drying sheds and racks	3,000
Storage bins and scales	2,500
Miscellaneous machinery, tools, railway side tracks, etc	1,000
Blacksmith and carpenter shops, tools, etc	500
Bog, 100 acres, at $20 per acre	2,000
	$24,600

If the bog can be drained, a combination peat machine can be substituted for the dipper dredge and scows, and the cost will thus be decreased. Self-propelling, combined digging, macerating, and spreading peat machines, with a capacity of 20 to 75 tons per day, will cost from $5,000 to $25,000 each. It is recommended that in selecting a peat machine, one should be chosen which has passed the experimental stage and which has demonstrated its adaptability to the work. European peat machinery can be purchased abroad at prices[19] which compare favorably with those asked for American machines, but the cost will be more than doubled before the machinery can be delivered to the bog, due to transportation and tariff.

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[18] C. A. Davis, *op. cit.* p. 102.

[19] These figures apply to 1913-14 prices. European machines are now almost unobtainable.

The cost of a 30-ton "Anrep" peat plant installed by the Department of Mines at Alfred, Ontario, was as follows:

Cost of a 30-ton "Anrep" Peat Plant[20]

100 acres of peat bog at $6 per acre	$ 600.00
Machinery: peat machine, locomobile, portable tracks, cars, cables, etc.	7,500.00
Blacksmith shop and equipment, office, loading platform, and railway siding	1,000.00
Draining bog	1,500.00
Office, furniture	100.00
	$10,700.00

Assuming a working season of five months, during which a total output of 3,300 short tons of air-dried machine peat (25 per cent moisture) is manufactured, the operating costs would be according to Canadian experience:

	Cost per ton
Labor and superintendence	$1.04
Cost of turning partly dried peat bricks	.07
Cost of piling bricks in small stacks	.10
Total cost on field exclusive of amortization and interest	$1.21
Amortization and interest	.33⅓
Repairs, fuel, oil, waste, etc.	.15
Total cost on field	$1.69⅓ or $1.70

Davis[21] states that the probable total cost of making machine peat in the United States by the methods outlined in the foregoing pages will be between $1.50 and $2.00 per ton.

SELLING PRICES

Air-dried machine peat made by the Moore system at Alfred, Ontario, sold for $3.50 per ton f.o.b. at the bog, and for as high as $5.75 per ton delivered in Ottawa. It is probable that retail prices ranging from $3.50 to $5 can be obtained for good machine peat in competition with cheap bituminous coal. Wholesale prices would probably be as low as $3 per ton (or lower) if peat fuel should come to be used to any large extent for manufacturing purposes.

MANUFACTURE OF PEAT BRIQUETS

Peat briquets are usually made from cut peat, which is dried in the air on the bog until its moisture content is reduced to about 40 per cent. The blocks are then ground to powder which is then artificially dried,

[20] B. F. Haanel, *op. cit.* p. 27.
[21] C. A. Davis, *op. cit.*

usually by steam driers, to about 15 per cent moisture, and then briqueted. There are two types of briqueting machines in use, the open and closed mold types. The open mold type is generally used. The dry peat powder is run into the mold and by means of a piston or plunger is subjected to a pressure of from 18,000 to 30,000 pounds per square inch. The capacity of the briqueting machines in use varies from about 15 tons to 50 tons of finished peat briquets per 24 hours.

Peat briquets are made in various shapes and sizes. Some are cylindrical, others prismatic, still others are pillow shaped. They are clean, compact, and dense, and they constitute the most attractive form of peat fuel. On the other hand, they sometimes have a tendency to crumble in the fire and are subject to greater breakage in handling than is machine peat.

Briqueting renders the peat more compact than any other process for the manufacture of peat fuel, so that the number of heat units per unit volume is increased.

There are no profitable peat briqueting plants in operation in the United States at the present time, although such are reported in Europe. The mechanical difficulties have been fairly well overcome, but the principal reasons for the failure of peat briqueting plants up to date seem to be the high cost of manufacture as compared with machine peat, and the absence of markets for the product.

COMPARATIVE COST OF PEAT BRIQUETS AND MACHINE PEAT

Peat briquets are much more costly to manufacture than machine peat for the following reasons. (1) A large proportion of the water must be eliminated by artificial drying. In Canada, an attempt has been made to overcome this difficulty by drying the peat in the sun on the surface of the bog and collecting the fine dry peat particles at frequent intervals, by means of a vacuum dust collector. (2) The plant requires more complicated machinery, more buildings, and more expensive equipment, which greatly increases interest and depreciation charges. (3) The cost of digging the raw peat is greater than the cost of mechanical excavation for machine peat.

Davis[22] states that the cost of manufacturing peat briquets in this country can hardly be less than $3 per ton, and in most cases it will be greater.

MANUFACTURE OF PRODUCER GAS FROM PEAT

METHODS OF MANUFACTURE

In the manufacture of producer gas, a portion of a charge of solid fuel, such as peat or coal, is burned to complete combustion, in order to

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[22] *Ibid.* pp. 102-5.

convert the remainder of the fuel to gas. The process differs from that of making illuminating gas in that no fixed carbon or coke remains.

There are four types of gas producers[23] for generating gas to be used to develop power: (1) the suction producer, which supplies gas direct to the gas engine by means of the suction stroke of the piston; (2) the pressure producer in which the gas is forced into a gas holder from whence it is supplied to the engine independently of the piston stroke: (3) the down draft, or inverted producer, in which the heavy gases are drawn by exhaust fans down through the fuel bed, where they are converted into carbon monoxide and hydrogen; (4) the double-zone producer, in which fires are maintained both over and under the fuel bed, and the gas is drawn off from the side of the producer.

The suction producer is probably most widely used, but it is not so well adapted to the use of peat fuel as to those fuels, such as anthracite coke and charcoal, which contains the minimum amount of tar. Since the gas is drawn directly into the engine, the tarry compounds carried over with the gas tend to clog the valves, although scrubbing devices have partially eliminated this trouble.

The pressure and inverted producers are the types best adapted to the use of peat fuel. There are no peat-burning gas producers in the United States operating at the present time on a commercial basis, but a number of such plants are in successful operation in Europe, especially in Germany and Sweden. These European gas producers are mostly of the down draft or inverted type.

The form of peat used in the European gas producers is machine peat and the processes by which it is manufactured are almost identical with those previously described under the discussion of peat fuel. The chief difference between the methods of manufacturing peat for use in gas producer plants and for ordinary peat fuel is that, at producer gas plants, the peat is often artificially dried with the waste heat from the engines and boilers, and by burning some of the peat to aid in the drying process. In some plants the producers are fed with artificially dried, hand-dug peat sods (cut peat). In this country it would be cheaper to use mechanically excavated machine peat.

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[23] For descriptions of these various types see *Bulletin* 16, U. S. Bureau of Mines, pp. 146-47, 1911. See also *Bulletins* 4, 7, 9, and 13, U. S. Bureau of Mines; also U. S. Geological Survey *Bulletins*, nos. 290 and 332; and Prof. Paper no. 48.

See also Producer Gas and Gas Producers by S. S. Wyer, 2nd ed. 1907.

The yield and calorific value of producer gas per ton of peat burned in various types of producers is shown in the following table:[24]

Make and type of gas producer	Source of peat	Yield of producer gas per short ton of peat	Calorific value per cubic foot of gas	Per cent of water in peat used	Authority
		cubic ft.	B. t. u.		
Mond	Italy	48,000	152.0	Water free	Nystrom
Koerting suction	Germany	54,000	150.0	26%	Ryan
Do	Sweden	80,000	.....	....	Kerr
Mond	England	80,000	145.0	Water free	Nystrom
Ziegler pressure	Germany	97,200	135.0	....	Ryan
Loomis-Pettibone down draft	North Carolina	72,400	109.7	Water free	U. S. Geol. Survey
Taylor Pressure No. 7	Florida	76,600	175.2	Water free	U. S. Geol. Survey

COST OF MANUFACTURE

Davis[25] shows that the cost per horse-power of producer gas plants varies from $108 for a 20-horsepower plant (excluding buildings) to $63 for a 2,000-horsepower plant, including buildings.

The cost of operating and maintaining producer gas plants is less than that for steam plants. No figures are available at the present time as to the cost of producer gas manufactured from peat in this country. At the by-product plant at Orentano, Italy, where about 17,400 tons of 33 per cent moisture peat were burned per year, 594 tons of ammonium sulphate were made in 1913 as a by-product in the generation of electric power from peat producer gas. The operating costs are given as follows:[26]

The cost of operation for 365 days is:

17,400 tons of peat for 350 days allowing losses for shut down of 7 hours per week or 15 days per year	$17,400.00
Wages on gas plant, including boiler attendants, $7,643, say	7,640.00
Wages on power house, $2,225, say	2,260.00
Repairs, stores, maintenance, say	2,000.00
Oil and stores for engine	200.00
Interest, depreciation, and amortization, say 14 per cent on cost of plant	21,610.00
Salary of plant manager, $1,200-$1,500, say	1,500.00
Chemists: 1 chief at $800.00	800.00
1 assistant at $400.00	400.00
713 tons of sulphuric acid at $7.37 per ton	5,260.00
Bags for packing ammonium sulphate at about $0.50 per ton	300.00
	$59,370.00

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594 tons of ammonium sulphate at $65 per ton	$38,610.00
Net cost of power per annum	$20,760.00
Net cost of power per k.w. hour on the basis of 165 k.w. hrs. for 350 days of 24 hours = 1,386,000 k.w. hours	1.5 cents

[24] C. A. Davis, *op. cit.* p. 150.

[25] *Ibid.*

[26] B. F. Haanel, *op. cit.* p. 108.

BY-PRODUCTS FROM THE MANUFACTURE OF PRODUCER GAS

Producer gas plants may be designed either for by-product recovery or for non–by-product recovery. The principal by-product which can be obtained from the manufacture of producer gas is ammonium sulphate $(NH_4)_2SO_4$, which, because of its high nitrogen content is in great demand as a fertilizer.

Peat-burning by-product recovery producer gas plants have been operated in Sweden, Germany, Italy, and England.

Two types of by-product recovery plants designed for peat fuel are in use in Europe: the Mond and the Frank-Caro. These plants operate on the same principle. The process depends on the fact that ammonia will be formed in gas producers at low temperatures and in the presence of steam. A small amount of air mixed with a large amount of steam is introduced into the producer. The ammonia and tar are collected by cooling and condensing, or the ammonia may be used with sulphuric acid, to make ammonium sulphate.

B. F. Haanel[27] describes the Mond by-product recovery producer gas plant as follows:

"A Mond by-product recovery power-gas plant consists, in general, of a producer, superheaters, mechanical washer, ammonia absorption tower, gas-cooling towers, air tower, and the necessary blowers, pumps, etc., for forcing air through the producer, and circulating the water and acid. When the solution of ammonium sulphate is evaporated at the plant suitable evaporators are provided.

"The gas leaves the producer at the top and passes through one or more superheaters into a mechanical washer. From the mechanical washer the gas enters the ammonia absorption tower at the bottom and leaves at the top, freed of its ammonia gas and some of its tar. From the ammonia absorption tower the hot gases pass through one or more water cooling towers, from which it is distributed to gas furnaces or is further purified for power purposes. The air which is supplied to the producer is first passed through the air tower where it absorbs heat and moisture from the hot water leaving the first gas-cooling tower. From the air tower the air passes through the superheaters in which some of the sensible heat of the producer gas is absorbed. From the superheaters the pre-heated air enters the producer near the bottom. Further saturation of the air is accomplished by adding low pressure steam generated in a boiler plant."

Theoretically, 1 short ton of dry peat will yield 94 pounds of ammonium sulphate. In the European plants the recovery is about 7[illegible] per cent efficient, i.e., approximately 70 pounds of ammonium sulphate are produced per short ton of peat burned, calculated on a moisture free basis. The peat as actually burned, however, contains about 3[illegible] per cent of water. It has been found that this moisture content gives the best results. The nitrogen content of the Minnesota peat will

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[27] B. F. Haanel, *op. cit.* p. 75.

average at least 2 per cent, and therefore the amount of ammonium sulphate which can be recovered here will be at least 140 pounds per short ton of theoretically dry peat, on the basis of a 75 per cent recovery.

At the Mond by-product recovery power gas plant at Orentano, Italy, where peat fuel is used, the quantity of sulphuric acid required is 1.2 times the weight of the ammonium sulphate produced.[28] The plant when operating with a capacity of 30 tons of absolutely dry peat per day produced about 594 short tons of ammonium sulphate per year. This required about 713 short tons of sulphuric acid, 50 Baumé, which, in 1913, cost the company $5,260.

At that time the market value of ammonium sulphate in Italy was about $65 per ton, which gave a total value of $38,610 to the annual production of ammonium sulphate. This was a by-product, as the plant was built primarily for the generation of power from producer gas.

It is very probable that peat will be used in gas producers in this country in the near future. The process has been demonstrated to be successful, and the problem now remaining is the development of suitable producers especially designed for burning peat. The recovery of ammonium sulphate as a by-product requires a much larger installation and special by-product recovery producers to make the process profitable.

OTHER TYPES OF PEAT FUEL

PEAT POWDER

Special blast burners are now in use for burning powdered fuel such as coal and sawdust, and recently similar burners have been devised for burning powdered peat. The use of powdered coal has already passed the experimental stage in this country, and this type of fuel is now commonly used at portland cement factories and at many boiler plants. It is claimed that the efficiency of the fuel is increased 15 to 20 per cent over ordinary grate firing.

Powdered peat has not yet been used in the United States on a commercial scale, but peat powder has been used for boiler firing at a few places in Canada.[29] Peat powder for boiler firing has been used successfully in Sweden.[30] There it is also used for firing locomotive boilers.

Results of tests by the Swedish government are summarized by Captain Ernst Wallagren, chief peat engineer for the Government, who says,

(1) "Peat powder could be produced . . . . in commercial quantities, if the plant were run for a full season at its present estimated annual capacity of 10,000

[28] *Ibid.*

[29] Canada Department of Mines, Mines Branch. *Bulletin* no. 4, 2nd ed., 1901, pp. 19, 31-44.

[30] E. Nystrom, Peat and Lignite; Their Manufacture and Use in Europe. Canada Department of Mines, Mines Branch p. 171-72. 1908.

metric tons, at a maximum cost of 8.50 kroner ($2.30) a metric ton (2,204 pounds), all charges included."

(2) "This cost could be reduced by increasing the size of the plant and the output or by making contemplated changes in equipment."

(3) "The peat powder when burned by the method used at Bäck was equal in fuel value to the best English coal, ton for ton."

(4) "This discovery makes Sweden independent of other countries for fuel supplies for industrial uses."

In the production of peat powder to be used for fuel, special methods of gathering and preparing the raw peat must be adopted. The system used in Canada[31] consists of gathering the peat as air-dry powder by the use of pneumatic collecting machines similar in principle to vacuum carpet cleaners. The surface of the bog is harrowed and after the top layer of loosened and disintegrated peat has been exposed to the sun and wind the moisture content is reduced to about 30 per cent. This dry powder is gathered in pneumatic collectors electrically operated and running on tracks. The air-dried peat is then screened and subjected to artificial drying, usually in rotary driers, to reduce the moisture content to 10 to 20 per cent. The peat is then sacked and marketed.

In Europe, the peat powder used is manufactured by grinding partially air-dried machine peat. The powder thus obtained is then dried further to the desired moisture content by artificial means.

The cost of manufacturing peat powder in Canada is given as about $1.50 per ton. In Sweden the cost of production is said to be slightly under $2.35 per ton. The cost of a plant of the Swedish type, having a capacity of 20,000 tons of peat powder per year is stated by the inventor of the process to be about $100,000.

PEAT COKE AND CHARCOAL

Peat charcoal has been made for hundreds of years in Europe by burning blocks of cut peat in dome-shaped heaps, covered with layers of brush and earth. This process is very little used at the present time and peat charcoal has been replaced on the market by peat coke, which has about the same strength and heating value as first class hardwood charcoal.

There have been several processes in use for the manufacture of peat coke but the one most extensively used now, and which has replaced most of the older methods, is the so-called Ziegler peat-coking process.[32] In this process, machine peat bricks are heated in retorts, specially designed for by-product recovery.

Only a comparatively small amount of peat fuel is needed to start the operation, which is continuous when once fairly under way, the heat

[31] C. A. Davis, *op. cit.* pp. 113-16.

[32] For a complete description of this process see E. Nystrom, *op. cit.* p. 176.

being obtained chiefly by burning a portion of the gases given off during the distillation of the peat. The by-products obtained from the dry distillation coking process include wood alcohol, ammonia and ammonium sulphate, acetic acid, illuminating and lubricating oils, paraffine wax, phenol, and asphalt.

Peat coke of good quality is equal to the best wood charcoal and is superior in quality to many of the cheaper grades of charcoal. It is compact and hard, the hardness depending largely upon the degree of maceration in the process of making the machine peat. The ash content depends upon the amount of ash in the raw peat. Good peat coke can only be obtained from well made machine peat manufactured from first-class raw material.

Davis[33] states that in the United States good peat coke should be produced in plants equipped to handle 100 tons of air-dried machine peat per day at a cost of from $3 to $3.50 per ton of coke, if the by-products are recovered and sold. Good peat coke, especially that which is of a quality suitable for use in metallurgical operations, could probably be sold for $6 to $12 per ton.

In Minnesota there are immense deposits of excellent peat suitable for the manufacture of coke, occurring within a few miles of the iron mining districts. The new steel plant at Duluth is located within fifty miles of some of these big peat bogs. While the peat coke produced in the United States in the past has been too soft to compete with coal coke, in the smelting of iron ores, it would be satisfactory if it were harder and more compact. The softness of the peat coke produced in the past has been due in large part to the fact that it was made from machine peat of inferior quality. The manufacture of machine peat in the United States has not yet reached the high state of development that obtains in Europe, but there seems to be no reason why machine peat of the highest quality can not be produced here. The domestic raw peat is fully equal in quality to that of Europe.

The proximity of the peat deposits to the iron ores of northern Minnesota offers an attractive field for investigation of the commercial possibilities of a peat coke plant in this region.

POSSIBLE USES OF PEAT IN THE IRON ORE INDUSTRY

Christianson[34] suggests the possibility of using peat in the iron ore industry. This subject is discussed, and Professor Christianson's views are given in Part II of this report. (See page 92.)

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[33] C. A. Davis, *op. cit.* p. 139.

[34] Peter Christianson, *Journal of the American Peat Society* 1 no. 4:86. Oct. 1915.

AGRICULTURAL USES OF PEAT

Peat lands have been successfully used for certain agricultural purposes in many localities in the United States and Europe. Peat soils are well adapted to the cultivation of certain crops such as forage plants and small grains, and all ordinary vegetables except asparagus. The agricultural uses of peat lands with special reference to Minnesota are discussed on pages 94 to 97 of this report in a special chapter by Professor F. J. Alway, chief of the Division of Soils, Minnesota Agricultural Experiment Station.

MISCELLANEOUS USES OF PEAT

PEAT FOR FERTILIZER FILLER

While peat is often used to advantage as a fertilizer by speading the dry material on the land, either alone or mixed with manure, it finds its chief value as a "filler" in artificial and chemical fertilizers.

The black, well decomposed varieties of peat are best suited for fertilizing purposes since they contain, as a rule, a higher proportion of nitrogen. It was formerly claimed that the nitrogen in raw peat was in such a form as not to be immediately available for plant food. On the other hand the advocates of peat fertilizers now claim that at least one third of the nitrogen is immediately available for plants.

The preparation of peat for fertilizer filler is simple. The peat is plowed and allowed to dry in the open air until the water content has been reduced as much as possible. It is then further dried artificially, usually in rotary driers, and ground to powder, after which it is sacked, ready for shipment.

The advantages claimed for peat "filler" over other fertilizer fillers are (1) its higher nitrogen content; (2) its deodorizing properties, permitting the use of waste animal matter; (3) its capacity to absorb water; (4) improved mechanical texture of the completed fertilizer; and (5) its cleanliness.

The greater part of the peat produced in the United States at the present time goes into the manufacture of fertilizer filler.

PEAT FOR STABLE LITTER AND PACKING MATERIAL

Large quantities of peat and peat moss are used each year for stable litter to take the place of straw, over which it has many advantages. Thoroughly dried peat is just as good as peat moss for this purpose. It makes a clean, springy, soft, absorbent bed for stock, and the odors of the stable are destroyed.

Dried peat of the more fibrous variety is largely used for packing material. For this purpose it is superior to most other materials used, and it is especially valuable in packing certain perishable goods, such as eggs, fruit, and vegetables, because of its well known preserving qualities.

It is an excellent non-conductor of heat and insures an even temperature and prevents freezing. It would make an excellent packing medium for dynamite and other explosives. Peat powder is especially valuable for packing fruit for long shipments. If these uses of peat were better known, it is certain that large quantities would be used for shipping fruit and eggs. Peat moss packing is used by florists and for packing fragile articles.

PEAT IN THE MANUFACTURE OF PAPER

Only the more fibrous varieties of peat are suitable for making paper. Most sphagnum moss peat is not fibrous enough. The built-up sedge-grass peat deposits contain the most suitable material for paper stock.

Up to the present time only heavy, coarse brown paper and cardboard have been manufactured from peat. The only plant operating in the United States is at Capac, Michigan. Davis[35] states that white paper can be made from peat by bleaching, but the coloring matter in peat is so durable that the cost of bleaching is prohibitive.

PEAT FOR WOVEN FABRICS

Horse blankets, and a few other coarse fabrics are woven from peat fibre. The fibrous varieties of peat are the only ones adapted to this purpose. The longer and stronger the fibre, the better the material. As a rule, the fibres in peat are strong but they are not long, consequently peat deposits suitable for woven fabrics are scarce. The fibres are first thoroughly cleaned and the long ones separated from the remaining material and treated to render them pliable.

It is reported that the fibre from certain sedge-peat is used, in Europe, after special treatment, for adulterating silk fabrics.

AMMONIUM COMPOUNDS

The principal ammonium compound manufactured from peat is ammonium sulphate, which is obtained as a by-product in the manufacture of producer gas. Ammonium sulphate is extensively used as a commercial fertilizer. Its production has already been described under the discussion of producer gas.

DYESTUFFS

It is possible that brown dyestuffs can be obtained from peat by adding alkaline substances to wet peat and draining off the water. The solution thus obtained is of a dark brown color. The brown substances which impart this color to the water may be precipitated as an insoluble brown powder which might be used as a dye.

ARTIFICIAL WOOD

Fibrous peat has been compressed and hardened into sheets and blocks to be used as finishing material. It is said that the material is

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[35] Charles A. Davis, *op. cit.* p. 169.

light, compact, waterproof, and could be made fireproof by the introduction of mineral matter into the fibre.

NITRATES

Nitrates for use as commercial fertilizer for agricultural purposes have been obtained from peat by treating a culture bed of peat with a dilute solution of ammonium sulphate. The bed is then inoculated with nitrifying organisms and allowed to stand for some time, after which the peat yields as high as 0.82 per cent of soluble nitrates. The process may be repeated five times and the total quantity of nitrates obtained may be as great as 4 per cent.

The bacteria produce these nitrates and other food substances for plants, and also render the mineral food constituents of the soil available.

These bacteria thrive best in soil with soluble soil humus. Peat is rich in humic acid and this humic acid can be converted into soluble humates by action of potassium or sodium hydroxide, or ammonium hydroxide. W. B. Bottomley[36] shows by numerous experiments on various kinds of plants under various conditions that the treatment of the soil with the bacterized peat enormously increases the fertility and yield of the soil. Results of tests on ordinary soil and soil treated with bacterized peat showed an average gain of 54 mgs. nitrogen per 100 gms. soil. Another test showed an average gain of 60 mgs. nitrogen per 100 gms. soil. This increase of nitrogen, if maintained over 1 acre of soil to a depth of 3 inches, would equal a dressing of 2,800 lbs. of nitrate of soda with a 15.6 nitrogen content.

Other tests made with soil consisting of 1 part bacterized peat, to 2, 4, and 8 parts loam, and ½, 1, and 2 parts sand, showed the plants on the treated soil to be twice to three times as large, after six weeks, as those on untreated soil.

MATERIALS FOR TANNING

Peat contains tannic acid, tannin, and related substances. These compounds are more abundant in peats containing a large amount of woody fibre. In Germany these tanning compounds have been recovered from peat and used in the tanning industry.

SANITARY AND MEDICINAL USES OF PEAT

The antiseptic, absorbent, and deodorizing properties of peat are well known, and clean peat fibre and peat powder has been used with good results for dressing wounds, and for various other uses around hospitals where material possessing these properties is in demand.

The great war has brought into use many substitutes and an important one of these is the use of sphagnum moss instead of cotton for surgical

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[36] W. B. Bottomley, The Bacterial Treatment of Peat. *Journal Royal Society of Arts* 62:373; *Journal American Peat Society* 7:70.

dressings. It is reported that the European armies have used millions of peat moss dressings. Hundreds of thousands of these dressings are being made in the United States and sent to France each month for the allied armies.

Sphagnum, especially the large leafy species, possesses many advantages over cotton for surgical dressings. The moss absorbs seven to ten times its own weight in liquid, while cotton absorbs only about six times its own weight. Sphagnum moss dries quickly, cotton slowly. The moss has springy qualities which make it softer to the touch of the wounded region, and the elasticity of the moss prevents compression of the dressing. Profusely bleeding wounds do not cause the sphagnum to clot as is the case with cotton. Sphagnum pads are renewed with less pain to the patient than cotton.

The preparation of sphagnum for use in surgical dressings is simple. The moss is first picked, care being taken to select clean living sphagnum of the large leafy species. All sticks, twigs, weeds, sedges, grasses, and other foreign substances should be sorted out by hand. The green, wet moss is then dried upon wire netting, or tables, to allow free circulation of air, after which it is graded. The fresh, green moss is of better quality than the faded or brown material. The moss is then sterilized, dried again, and packed in bags, ready for shipment. The work of gathering the sphagnum for the use of the armies is chiefly done by women and children who volunteer their services. The newly gathered moss is shipped in sacks to central drying and sterilizing stations, where it is manufactured into surgical pads or dressings.

PART II

THE PEAT DEPOSITS OF MINNESOTA

DISTRIBUTION OF PEAT IN MINNESOTA

GEOGRAPHIC DISTRIBUTION

There is peat in nearly every county in Minnesota, but by far the largest, deepest, and most important deposits occur in the "muskeg" swamps and open bogs and marshes of the northern part of the state. Three areas in Minnesota are without peat; one in the "driftless area" in the extreme southeast corner of the state; a second in the extreme southwest corner; and the third along the western border, adjoining North and South Dakota. This last region lies chiefly within the Red River Valley, which is a treeless area covered with a thick deposit of fine silt and clay.

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

RELATION OF DISTRIBUTION TO TOPOGRAPHY AND GEOLOGY

All the peat deposits in Minnesota occur in glaciated areas. The distribution of the larger and most important peat bogs, as outlined in the preceding paragraphs, coincides with the flat areas. These great bogs and swamps occupy, for the most part, portions of the beds of two ancient lakes which existed at the close of glacial time. The larger of these old lakes is known as glacial Lake Agassiz, and its history and influence on the origin of the peat deposits are discussed in detail in the subsequent pages of this report. The other lake, which is older than Lake Agassiz, covered parts of Koochiching, St. Louis, and Lake counties. Its outlet was across the Mesabi Range along Embarras River. Many of the peat deposits of St. Louis and Lake counties occur in the old bed of this pre-Agassiz lake.[37] Many of the smaller peat bogs in Minnesota occur outside of the areas once occupied by these lakes, in regions of irregular, hilly topography. Most of the low hills, so common to central Minnesota, represent glacial moraines formed from rock debris. They were left behind by the ice when it receded

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[37] Frank Leverett, written communication. 1915.

to the north at the close of the Glacial Period. Many of the peat bogs in these morainic regions occupy basins which were once the sites of small lakes or ponds. Others were originally swamps and marshes in the undrained depressions in the glacial drift. Thus it is seen that the peat bogs are not confined to any one type of topography, but they are widely scattered over the state in hilly as well as in flat regions.

THE DISTRIBUTION OF THE PEAT DEPOSITS BY COUNTIES

The distribution of peat bogs in Minnesota and the relative quantities of peat in the different counties is shown in the following table:

Table Showing Distribution of Minnesota Peat Bogs by Counties

County	*Relative quantity of peat*	*Description of bogs*
Aitkin	Large	Sphagnum; heath; sedge
Anoka	Large	Sedge-grass; open bogs
Becker	Moderate	Small depressions in drift. Some marl
Beltrami	Immense, largest in state	Muskeg swamps. Tamarack, spruce, and cedar. Some marl
Benton	Small	Shallow. Sedge-grass
Big Stone	None	
Blue Earth	Moderate	Small but deep. Sedge-grass. Open bogs
Brown	Small	Small. Sedge-grass. Open marshes
Carlton	Large	Muskegs and open sedge bogs
Carver	Moderate	Small open grass bogs
Cass	Moderate	Small muskegs and open sedge bogs
Chippewa	Small	Very small meadow bogs
Chisago	Moderate	Small muskegs and meadow bogs
Clay	None	
Clearwater	Moderate	Small muskegs and open sedge bogs
Cook	Small	A few small muskegs
Cottonwood	Small	Small open grassy meadows, and some marshes
Crow Wing	Large	Open sedge bogs and very small muskegs. Some marl
Dakota	Small	Grass-sedge river marshes. Silty
Dodge	Very small	Silty muck. In meadows and marshes
Douglas	Moderate	Open sedge bogs. Few small muskegs. Some marl
Faribault	Small	Shallow open meadows and marshes
Fillmore	None	In driftless area
Freeborn	Moderate	Shallow, open sedge-grass marshes
Goodhue	None	
Grant	None	
Hennepin	Moderate	Small sphagnum and open sedge bogs. Some marl
Houston	None	In driftless area
Hubbard	Moderate	Small sphagnum and open meadow bogs
Isanti	Moderate	Small sphagnum and open meadow bogs
Itasca	Very large	Muskegs and filled lakes. Some with marl
Jackson	Small	Open meadow bogs and marshes
Kanabec	Small	Open meadows and few small sphagnum bogs
Kandiyohi	Small	Open meadows and grass-sedge marshes
Kittson	None	
Koochiching	Immense	Muskeg swamps and heath bogs. Spruce, tamarack, cedar, some marl
Lac qui Parle	None	
Lake	Moderate	Muskeg swamps and open heath bogs
Le Sueur	Small	Open sedge-grass meadows and river marshes
Lincoln	None	
Lyon	None	
McLeod	Small	A few small peat meadows
Mahnomen	Small	Shallow grassy marshes
Marshall	Very large	Big shallow open sedge-peat marshes. A few muskegs

County	Relative quantity of peat	Description of bogs
Martin	Small	Few open marshes and meadows around lakes
Meeker	Moderate	Small open bogs around lakes
Mille Lacs	Moderate	Tamarack-sphagnum swamps and open sedge bogs
Morrison	Moderate	Mostly open sedge-grass meadows, rather silty
Mower	None	
Murray	Small	Small open marshes around lakes
Nicollet	Moderate	Open meadow bogs and marshes
Nobles	Very small	Lake marshes, cattails, sedges, etc.
Norman	None	
Olmsted	Very small	Chiefly muck. In meadows
Otter Tail	Moderate	Small sphagnum and open sedge-grass bogs. Some marl
Pine	Moderate	Small sphagnum and open sedge-grass bogs. Some marl
Pipestone	None	
Polk	Small	Open sedge-grass marshes
Pope	Moderate	Sedge-grass meadows and sphagnum bogs. Some marl
Ramsey	Moderate	Open sedge bogs. Few small muskegs
Red Lake	Small	Mostly open sedge-grass marshes
Redwood	Very small	Meadows. Mostly muck
Renville	Very small	Meadows. Mostly muck
Rice	Moderate	Open grass-sedge bogs and meadows
Rock	None	
Roseau	Very large	Open sphagnum and sedge bogs
St. Louis	Very large	Tamarack-spruce muskeg swamps. Muskegs. Open heath bogs
Scott	Small	Small grass-sedge meadows and marshes
Sherburne	Moderate	Open meadows and small tamarack swamps
Sibley	Very small	Small open marshes and meadows
Stearns	Moderate	Open sedge-grass marshes
Steele	Very small	Open sedge-grass marshes
Stevens	None	
Swift	None	
Todd	Moderate	Small muskegs and open sedge bogs
Traverse	None	
Wabasha	None	
Wadena	Moderate	Small tamarack swamps and open sedge marshes
Waseca	Small	Open sedge-grass bogs around lakes
Washington	Small	Small tamarack and sedge bogs
Watonwan	Very small	Small grass-sedge meadows. Mostly muck
Wilkin	None	
Winona	None	
Wright	Moderate	Small tamarack swamps and open sedge bogs
Yellow Medicine	None	

TOTAL QUANTITY OF PEAT IN MINNESOTA

AREA AND THICKNESS OF PEAT DEPOSITS

According to the report of the state engineer[38] Minnesota had originally about 10,000,000 acres of swamp lands, or lands too wet in their natural condition for agricultural purposes. This vast area comprises about one fifth of the total area of the state. Not all of this swamp land was covered with peat, however, and millions of acres have been drained and converted into productive farms, while additional areas are being reclaimed each year. From the investigations made in the preparation of this report, it is estimated that about 7,000,000 acres, or approximately two thirds of the original swamp area was originally covered with peat deposits, varying in thickness from a few

[38] George A. Ralph, Engineers Report State Drainage Commission p. 9. 1913.

inches to 30 feet or more. Of this peat land, it is estimated that about 5,217,000 acres are covered with peat at least 5 feet thick. Since this thickness (5 feet) is the minimum which can be profitably worked in the manufacture of machine peat fuel, only the deposits which attain a depth of 5 feet have been included in the estimate of the peat fuel resources of Minnesota. The average thickness of the peat in some counties in the state is greater than 5 feet, as in Beltrami, Koochiching, and St. Louis counties, where the average is 7 feet. The quantity of peat fuel (machine peat) available has been estimated separately for each county containing large peat deposits with an average thickness of 5 feet or more. The total quantity of 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 per foot of thickness of peat is approximately 6,835,300,000 tons.

The estimates for the different counties containing important peat deposits are given below.

Table Showing Approximate Quantity of Peat Fuel of Good Quality Available in Minnesota, by Counties

County	Area of peat deposits, acres	Average thickness of peat, feet	Quantity of air-dried machine peat fuel available, tons
Aitkin	397,300	6	476,760,000
Anoka	30,000	7	42,000,000
Becker	12,800	5	12,800,000
Beltrami	1,299,200	7	1,818,880,000
Carlton	35,000	10	70,000,000
Cass	75,000	5	75,000,000
Clearwater	128,000	5	128,000,000
Crow Wing	61,300	6	73,560,000
Douglas	5,000	6	6,000,000
Hubbard	10,000	6	12,000,000
Isanti	10,000	5	10,000,000
Itasca	250,000	6	300,000,000
Koochiching	1,000,000	7	1,400,000,000
Lake	150,000	6	180,000,000
Marshall	50,000	5	50,000,000
Mille Lacs	25,000	5	25,000,000
Morrison	10,000	5	10,000,000
Otter Tail	75,000	5	75,000,000
Pennington	10,000	5	10,000,000
Pine	75,000	5	75,000,000
Ramsey	1,500	5	1,500,000
Roseau	250,000	5	250,000,000
St. Louis	1,192,000	7	1,668,800,000
Todd	10,000	5	10,000,000
Wadena	5,000	5	5,000,000
All others	50,000	5	50,000,000
Total	5,217,100		6,835,300,000

It is believed that the above estimates are conservative. Soundings in areas which on account of high water it was not possible to visit in preparing this report, will probably show that the average thickness of the peat in some counties is greater than the thickness given above.

COMPARISON WITH OTHER REGIONS

It is estimated by Charles A. Davis[39] that the total quantity of machine peat available in the United States is approximately 12,888,500,000 tons. If the above figures are approximately correct, they show that Minnesota contains more than half of the total peat in the United States. Huels estimated that there are between two and three billion tons of air-dried machine peat in Wisconsin.[40] This quantity is somewhat less than half of the amount available in Minnesota. If the 6,835,300,000 tons of peat in Minnesota were converted into machine peat bricks and sold at $3 per ton, it would have a value of $20,505,900,000.

HISTORY OF THE FORMATION OF MINNESOTA PEAT DEPOSITS AS RECORDED BY THE PLANT REMAINS FOUND IN THEM

The history of all the Minnesota peat deposits dates back to the close of the last Glacial Period in North America. After the recession of the ice, the first vegetational zones were controlled by physiographic rather than by soil conditions. There were numerous lakes and vast undrained marshy tracts over which the waters from the receding ice spread their burdens of glacial debris. The drainage of the northern part of Minnesota and the adjacent region was prevented because the waters were held back on the north by the huge dams of ice of the receding glaciers. This resulted in the formation of a vast lake called glacial Lake Agassiz, which covered much of northwestern and north central Minnesota, and extended northward far into Manitoba and Ontario, and westward into North Dakota. It is in the old bed of this lake that most of the great peat bogs in Minnesota are found. As the ice melted and receded farther northward, Lake Agassiz reached its maximum size, and the waters were drained to the south through the Minnesota River. Gradually the level of the lake was lowered, partly by geologic uplift of the land and partly by the cutting down of the outlet. Finally, there was a change in the outlet of Lake Agassiz, from the southern end to the northern, and the lake was gradually drained. The southern borders of the lake were the first to dry up, and as the waters became shallower and shallower the lake receded northward to its present position in Manitoba, where Lake Winnipeg is a remnant of this former glacial lake. With the recession of the lake waters, large

[39] Charles A. Davis, *op. cit.* p. 13.

[40] F. W. Huels, The Peat Resources of Wisconsin. *Bulletin* 45. Economic Series 20. Wisconsin Geological and Natural History Survey p. 171.

areas were converted into marshes which became the sites of peat accumulation.

Much of the recently denuded land to the south probably consisted of low tundras upon which there gradually appeared mosses, lichens, and grassy meadows, with occasional stunted trees.[41] This tundra type of vegetation was later displaced by land species, and gradually the surface became more and more like the present one. South of the region covered by glacial Lake Agassiz also there were numerous small lakes and marshes. Many of these lakes have remained as open bodies of water, while others became filled with peat. The marshes have developed into swamps and bogs of various types.

While the draining and drying up of Lake Agassiz was gradual, it probably proceeded more rapidly than the rate of peat formation, so that large tracts were converted into marshes or flat, undrained areas. The marshes soon became covered with marsh or swamp vegetation, some of which gained a foothold while the land was still covered with shallow ponds. Among the first plants to appear was sphagnum, or peat moss. Many of the largest peat deposits in this region consist almost entirely of the remains of sphagnum from top to bottom. Numerous exposures were seen in the sides of deep drainage ditches where sphagnum peat rests upon the surface of lake-washed glacial till or clay.

A careful study of the plant remains in the different layers of a peat bog, from bottom to top, together with knowledge of the character of the topography of the bottom, reveals the history of the bog. Upon the basis of such evidence, it is possible to divide the peat deposits of Minnesota into two great groups: (1) *filled-in deposits,* formed by the filling of lakes or ponds with plant remains; and (2) *built-up deposits,* which have accumulated on flat, wet, marshy surfaces, and which do not represent filled lakes. These two types correspond to the European "low-moors" and "high-moors." In the subsequent pages of this report, whenever the term "built-up deposit" is used, it refers to a peat deposit which has accumulated in some manner other than by the filling of a lake or open body of water. Since sphagnum does not invade open bodies of water such as lakes and ponds, but appears only after such water bodies become filled or partly filled with peat, it is concluded that the large bogs of northern Minnesota composed of sphagnum from top to bottom, and resting directly on lake-washed glacial till or clay, have not formed by the filling of lakes, and hence represent "built-up deposits." Further evidence to strengthen this conclusion is found in a study of the character of the topography of the bottoms of these bogs, as revealed by several thousand test holes. When the peat

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[41] Alfred Dachnowski, *op. cit.* p. 215.

consists almost entirely of sphagnum, the bottom of the bog is usually flat, though not necessarily level. The bottom often has a uniform slope of ten to twenty feet per mile, and in such cases evidently represents a portion of a large, undrained, glacial, outwash plain, or an expanse laid bare by the disappearance of the waters of a large lake, such as glacial Lake Agassiz. On the other hand, most peat deposits which show from their plant constituents that they represent filled lakes occupy typical basin-shaped depressions, with the deepest peat in the interior, which become shallower in all directions toward the shore.

Shaler[42] states that he has seen near Eastport, Maine, a number of instances in which the growth of sphagnum, invading forests, has brought the surface to such a wet condition that even those trees that love water most are unable to maintain their foothold. Such instances were not observed in Minnesota. While the structure of the successive strata in some of the northern Minnesota bogs shows the presence of layers of logs and roots of trees ten and even twenty feet beneath the existing surface, these buried forests were not killed by the invasion of peat moss. The peat was usually there first, as is shown by the presence of peat, free from woody fibre, beneath the lowest layer of wood in most of the bogs where buried trees were found. The trees are mostly tamarack and spruce, and, as already pointed out, these are the last plants to make their appearance on a typical muskeg. They are able to take root only after the surface of the bog is built up above the ground water level. The buried forests are accounted for by a slight elevation or lowering of the water table which changed the moisture conditions at the surface of the bog to such an extent that the trees could no longer live, and consequently they became buried in the peat.

CONDITIONS CONTROLLING THE FORMATION OF MINNESOTA PEAT DEPOSITS

THE INFLUENCE OF CLIMATE

In Minnesota the effect of the influence of climate upon peat formation is marked. In the southern part of the state, where the winters are milder, and the summers warmer, the peat deposits are all comparatively shallow. They are also relatively few in number as compared with the northern part of the state, but this scarcity of deposits in the south is due chiefly to another factor, that of topography, the effects of which will be discussed later.

According to Purssell[43] the mean annual temperature of Northern Minnesota, where all the large, deep peat bogs occur, varies from 35

[42] N. S. Shaler, General Account of the Fresh Water Morasses of the United States. U. S. Geological Survey. *10th An. Report* p. 295. 1890.

[43] Frank Leverett, and U. G. Purssell, Surface Formations and Agricultural Conditions of Minnesota, *Bulletin* 12. Minnesota Geological Survey p. 13. 1915.

to 40 degrees Fahrenheit which is 8 to 10 degrees colder than that of the southern portion of the state. Purssell[44] also points out that while the heaviest rainfall is in the eastern and southern portions, the rainfall is fairly abundant throughout the entire state, and the minimum amount of 20 inches is in the extreme northwest corner where there is little or no peat. Considering only the northern half of the state, where the peat is best developed, the precipitation increases steadily to the eastward, as does also the quantity of peat, except in the extreme northeast corner, where there is very little peat owing to the topographic relations of the surface.

The usual effect of the humidity of the air on peat formation is also illustrated in Minnesota. The following table shows that the northern part of the state, where the largest and deepest peat bogs occur, has higher humidity than the more southern portions.

Station	Location in state	Abundance of peat	Mean annual humidity
St. Vincent..	Extreme northern part	Large quantities lie east of St. Vincent.	8 a.m. 86; 8 p.m. 77
Duluth......	Northern part.......	Large quantities......................	8 a.m. 81; 8 p.m. 71
Moorhead...	Northwestern.......	Some peat lies east of Moorhead.......	8 a.m. 86; 8 p.m. 72
St. Paul.....	South central.......	Considerable. Bogs small............	8 a.m. 81; 8 p.m. 64

The most important consideration in regard to the influence of climate upon the origin of Minnesota peats has to do with the climate of the past. The peat deposits have been accumulating for thousands of years, and the rate of accumulation has varied from time to time, as shown by evidence preserved in the structure of the peat. These fluctuations have undoubtedly corresponded in a general way with climatic changes. The close of the Glacial Period marks the beginning of the Minnesota peats. The climate at this time was undoubtedly colder and the atmosphere was probably more humid than now. This higher humidity would be caused by the large areas of undrained land, and numerous lakes resulting from the melting of the ice. Under such conditions, peat would accumulate rapidly after these water bodies and swamps became fringed with vegetation. In the course of time, as the ice retreated farther northward, and the areas of standing surface waters became reduced by the evaporation and run off, the climate became somewhat milder and the air less moisture laden. This naturally led to a slackening in the rate of accumulation of the peat. Gradually as the climatic conditions became more stable, the rate of peat accumulation adjusted itself to the present conditions. Peat is still in process of accumulation in practically all of the Minnesota deposits.

[44] *Ibid.* p. 23.

THE INFLUENCE OF TOPOGRAPHY

The topography of the land surface has been the most important factor in controlling the distribution of peat in Minnesota, while the climatic conditions have controlled the quantity which has formed. No matter how favorable the climate may be, peat can not accumulate unless the topography is such that lakes, ponds, swamps, or other moist depressions prevail.

TOPOGRAPHY OF MINNESOTA

All of Minnesota, with the exception of a small area in the extreme southeast corner, has been glaciated, and consequently the surface materials and their topographic attitudes are in a large measure independent of the pre-glacial erosion surface upon which they lie. The principal topographic divisions within the state consist of: (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 notable 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 northeastern part. There are a few rock hills which rise through the drift. These lie chiefly in the northern portion of the state, but there are also some in the southeast corner. The largest and most numerous moraines occur in northern and central Minnesota, and it is in the depressions between these morainic hills that many of the small, but deep, peat beds have accumulated.

The principal drainage system is that of the Mississippi River and its tributaries. The largest of these tributaries is the Minnesota River, which joins the Mississippi at Fort Snelling, between Minneapolis and St. Paul. The northwestern part of the state drains northward, through the Red River of the North, the waters of which eventually reach Hudson Bay. A small area drains directly into Lake Superior.

The maximum relief of Minnesota is 1,628 feet. The altitudes range from 602 feet, the level of Lake Superior, to 2,230 feet, on the highest knolls in Cook County, in the extreme northeastern corner of the state. The greater part of Minnesota has a gently undulating surface of slight relief with numerous flat areas which mark the sites of former lakes, or outwash plains below moraines.

TYPES OF BASINS AND DEPRESSIONS CONTAINING PEAT

The principal types of basins or depressions in which peat has accumulated are:

1. Depressions of glacial origin
    1. Basins between morainic hills

   2. Slight depressions in undulating drift surfaces
   3. Kettle holes
   4. Basins formed by dams of morainic debris across old stream channels
   5. Old lake beds
2. Depressions not of glacial origin
   1. Valleys of existing streams
   2. Depressions due to post-glacial erosion
   3. Basins formed by construction of beaver dams across streams

Depressions of Glacial Origin

Basins between morainic hills.—When the retreating ice sheet disappeared from this region, all of the rock and soil debris carried by the ice was deposited. Along the edges of ice lobes and at the front or southern edge of the ice, this debris accumulated in great masses which were left behind to form moraines. These moraines are characterized by extremely irregular topography, without any system of drainage. For the most part they consist of a series of rounded hills of different shapes, irregularly grouped, between which are deep hollows without drainage. These hollows are often the sites of small lakes. In fact, most of the lakes of northern and central Minnesota are of this type. In many of these lakes peat is now in process of forming. Many others have long since been completely filled with peat. Figure A, Plate V, shows a small muskeg of this type which has been formed between two morainic ridges. These peat-filled basins now constitute the typical small bogs which are so numerous throughout north central Minnesota, and especially in the so-called "Park Region."

Figure 2, page 40, shows an area of typical moraine topography in northern Minnesota. The depressions and kettle holes in the drift have become the sites of lakes and marshes, many of which contain peat. Compare this topography with that shown in Figure 3, page 41, which represents a peat bog formed on a broad, flat outwash plain a few miles north of Minneapolis. In this region the surface is gently undulating and the differences in elevation are small. The peat has accumulated in the broad, shallow depressions to a depth of 6 or 8 feet.

Slight depressions in undulating drift surfaces.—In regions beyond the moraines, where the waters of the melting ice have washed down and worked over the materials from the newly deposited drift, the land surface is usually gently undulating. The slight irregularities of surface are due in part to post-glacial erosion, but chiefly to the original conditions of imperfect or uneven spreading of the material by the constantly shifting streams from the ice front. In many of the shallow depressions which are common over these regions, peat has accumulated,

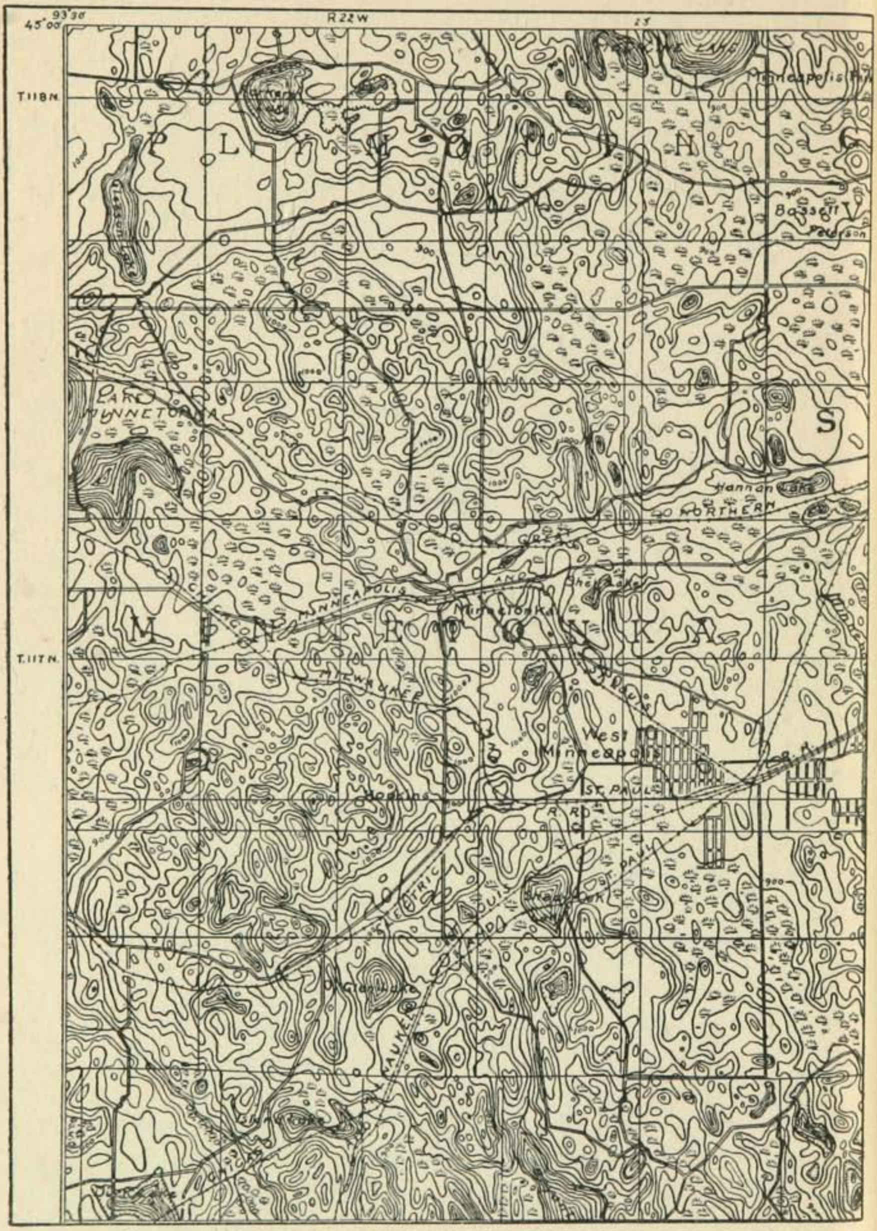

FIGURE 2. TYPICAL MORAINE TOPOGRAPHY SHOWING PEAT BOGS DEVELOPED IN DEPRESSIONS IN THE DRIFT. COMPARE THESE BOGS WITH THOSE SHOWN IN FIGURE 3. FROM U. S. G. S. TOPOGRAPHIC MAP OF MINNEAPOLIS QUADRANGLE.

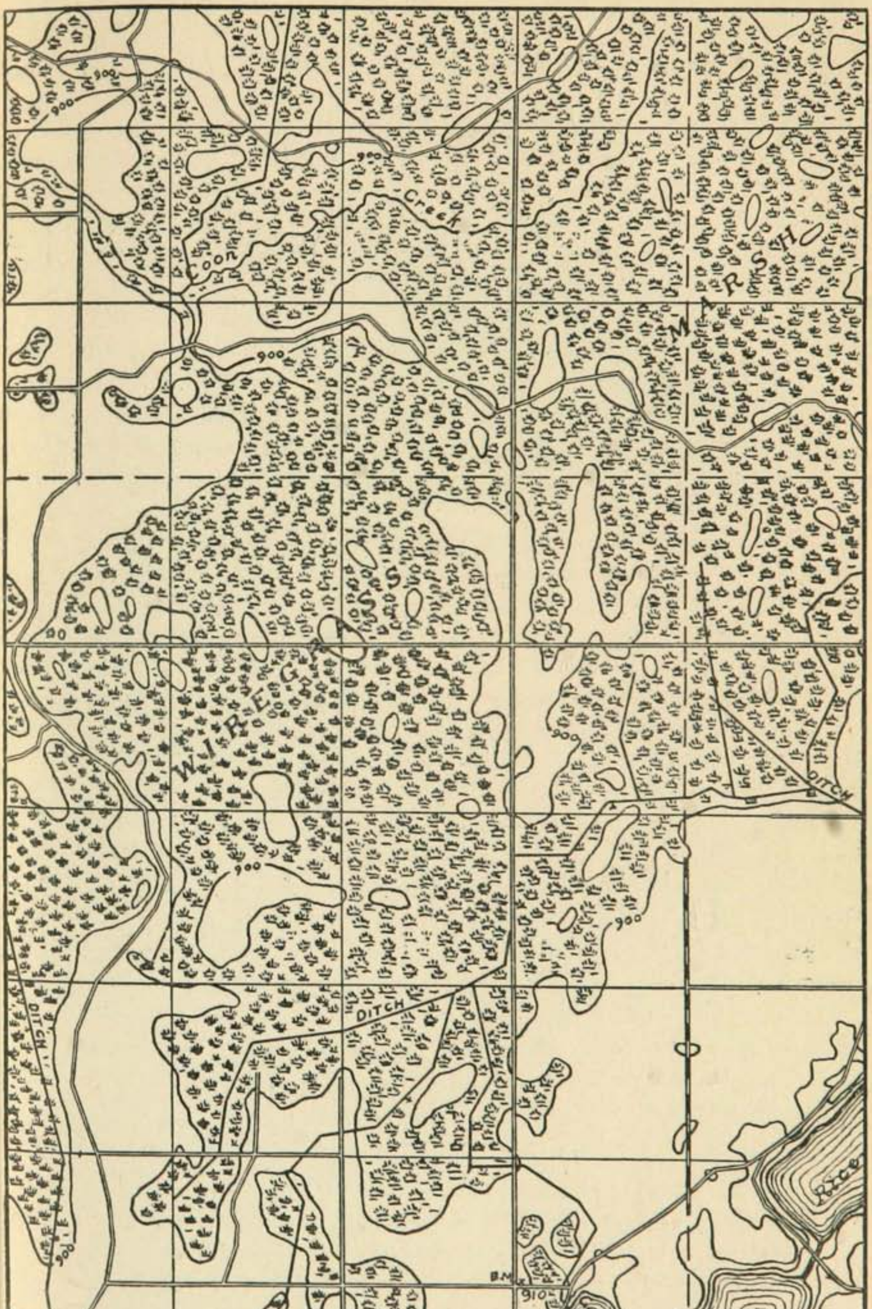

FIGURE 3. TYPICAL OUTWASH PLAIN TOPOGRAPHY, SHOWING FORMATION OF PEAT BOGS IN BROAD, SHALLOW DEPRESSIONS IN THE GENTLY UNDULATING SURFACE. TAKEN FROM U. S. G. S. TOPOGRAPHIC MAP OF WHITE BEAR QUADRANGLE. SQUARES ARE SECTIONS.

sometimes to a thickness of 6 or 8 feet. Figure B, Plate V, shows a marsh of this type.

Kettle holes.—Strictly speaking, there is little difference between kettle holes and depressions of the types just described. The term is used here to designate the deeper and steeper sided morainic basins frequently observed in parts of northern Minnesota, and which are often filled with peat to a depth of 20 to 25 feet. Such deposits are filled lakes.

Basins formed by dams of morainic debris.—Depressions of this type are less common in Minnesota for the reason that the material constituting the moraines has usually choked up the entire channels of pre-glacial valleys, instead of forming dams across them. However, a few examples of peat deposits were noted occupying depressions due to dams of drift.

Old lake beds.—Since practically all the lakes in Minnesota are either directly or indirectly due to glacial influences, it follows that they must occupy basins of one or another of the types described above. Some of these lakes dried up before they became filled with peat. Others were drained by the gradual lowering of the outlet due to the erosion accomplished by the stream flowing out. Still others have been filled with peat to the original water level. In some cases, even the old beds of lakes which were drained have become the sites of peat accumulation, especially where the beds remained wet and marshy.

By far the greater part of the peat in the state occurs in a series of immense bogs and muskeg swamps, which occupy portions of the old bed of Lake Agassiz. These may properly be classed as old lake bed deposits, but, on the other hand, they present features different from the other deposits occupying lake basins. These large swamps, although they form a part of a vast shallow depression, when taken singly do not occupy depressions in the drift. Some are on regularly sloping flat surfaces, while others seem to cover undulating surfaces. For these reasons, and because of their importance, it has been thought best not to include these great peat swamps under the head of "old lake beds" but to discuss them separately.

Depressions Not of Glacial Origin

Valleys of existing streams.—Nearly all of the streams in Minnesota are flowing in valleys which have been eroded since the retreat of the ice sheet. A few of these have chanced to reëxcavate parts of their original pre-glacial channels, but most of them have not yet cut through the mantle of glacial drift except along the steeper portions of their courses. In the broader portions of some of these stream valleys, on flood plains and low terraces, peat deposits have formed. The peat

A. PEAT BOG FORMING ALONG THE CHANNEL OF A STREAM FLOWING IN BROAD, SHALLOW VALLEY BETWEEN LOW DRIFT HILLS. NEAR BEMIDJI, BELTRAMI COUNTY

B. PEAT BOG FORMING IN SMALL LAKE CAUSED BY BEAVER DAMS. ITASCA STATE PARK. NOTE THE BEAVER LODGE IN BACKGROUND

in such localities is usually shallow and impure. Its shallowness is due no doubt to the fact that the conditions have not been constant for sufficient time to enable the peat to accumulate in quantity. The impurity of the material is the result of the washing in of silt and sand by the stream in periods of high water. Figure A, Plate VII, shows a peat bog occupying the valley of a stream flowing in a broad, shallow valley between two hills of glacial drift.

Depressions due to post-glacial erosion.—Under this type are included all those depressions of the surface, other than stream channels, which are the result of post-glacial erosion. On steep slopes the results of such erosion are frequently striking, while on gentle slopes there may be scarcely any noticeable result. However, when the results are measured over long periods, the total effect is large. Many of the depressions in the surface of the drift throughout the state are the results of erosion of this nature. Once the depression is formed, it will continue to be enlarged at an increased rate, unless the vegetation increases faster, and eventually checks further erosion. Under such conditions, these shallow basins may rapidly fill with peat.

Basins formed by the construction of beaver dams.—Several interesting examples of the influence which beavers have upon the modification of the surface of the land were observed during the course of the field work in connection with this report. The most conspicuous case was found in Itasca State Park, where beavers had built a number of dams across stream valleys. In one case the waters were dammed back, forming a lake 25 or 30 acres in area and 6 or 8 feet deep. The main dam, which is about 8 feet high, was constructed many years ago, and a considerable quantity of peat has accumulated around the edges of the pond (Figure B, Plate VII). At another locality in the Park, small peat bogs were seen, which had evidently been formed in the same way, although the old beaver dams were no longer visible. Other instances of peat bogs resulting from beaver dams have been observed in the northwest. Davis[45] has found evidence that the extensive peat bog at Capac, Michigan, is the result of beaver work.

PEAT DEPOSITS NOT OCCUPYING DEPRESSIONS

The largest peat deposits in Minnesota do not occur in basins, but on large, flat, featureless areas, which represent old lake beds or outwash plains. The largest of these swamps lies within the old bed of ancient Lake Agassiz. It should be pointed out that while these great peat bogs are flat on top, they are seldom level. The map of Beltrami County (Plate II), on which the contours are shown in the northern

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[45] Charles A. Davis, Peat: Essays on Its Origin, Uses, and Distribution in Michigan. Mich. Geol. Survey. *An. Report* p. 119, 1906.

part, illustrates this. In this locality the gradient, or slope, of the present surface of the peat, which is approximately parallel to the bottom of the deposit, is about 10 to 20 feet per mile towards the northeast. The gradient decreases toward the east to less than 10 feet per mile. The average slope of the surface from the west central part of Koochiching County, north to Rainy River, is about 4 feet per mile. The measurement of the surface slope of a peat bog does not necessarily disclose the character of the underlying land surface upon which the peat accumulated. Even in the areas described above, the data from several thousand soundings show that there are many inequalities and minor depressions in the underlying glacial drift, as well as some very large and deep ones. They have all been covered with peat and the bogs now present a smooth and regularly sloping surface. It is seldom possible to determine from a casual inspection of the surface of the bogs in this region whether the peat is 6 feet deep or 20 feet deep. The portions of these immense swamps in which the depth of the peat increases from 7 or 8 feet to 15 or 20 feet, or more, are apparently small basins or depressions within the area covered by glacial Lake Agassiz, which remained as isolated lakes and ponds for some time after the waters of the main part of the ancient lake receded. These smaller isolated bodies of water, which dotted the region as the great lake disappeared, became filled with peat, while the intervening areas were still marshes or dry land. Gradually the accumulation of peat spread to these flat marshy tracts surrounding the filled lakes, so that, in the course of time, the entire region was covered with peat. As successive generations of plants added their substance to the accumulating deposit, the general level of the surface of the bog was gradually raised and inequalities were smoothed over. Portions of two of these big flat bogs are shown on Plate VIII A and B. This process continued until a condition of equilibrium was reached between the rate of plant decay and the annual addition of vegetable matter. The rate of decay increased as the deposit became thicker, due to the fact that there was insufficient water to saturate the dead vegetable matter above a certain level. This level, which marks the limit of peat formation, varies from year to year depending chiefly upon climatic conditions, drainage, etc. Thus it happens that in some portions of these immense swamps, peat has been continuously forming, while in other localities no additions have been made to the thickness for many years.

INFLUENCE OF GEOLOGY ON PEAT ACCUMULATION IN MINNESOTA

The character of the bed rock does not seem to have any direct influence on peat formation in Minnesota. The bed rock, however, has exerted a rather important influence indirectly. A complex rock

A. TAMARACK SWAMP IN WHICH THE PEAT HAS BEEN BUILT UP ON A FLAT SURFACE ONCE OCCUPIED BY A PORTION OF LAKE AGASSIZ.
BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

B. VIEW LOOKING ALONG DRAINAGE DITCH THROUGH A TYPICAL TAMARACK SWAMP WHICH HAS BEEN PARTLY BURNED. PEAT ABOUT 8 FEET DEEP.
BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

surface of varying resistance, when glaciated, will produce greater surface irregularities than a horizontal surface such as frequently exists in areas of stratified rocks. These irregularities of surface become sites of lakes or swamps in which peat accumulates. In Minnesota the greatest diversity of rocks occurs in the northern portion and it is there also that the topography is roughest and the peat bogs most numerous. This may be partly due to the geologic causes just mentioned. The glacial influences on peat formation are discussed below.

RELATION OF PEAT TO GLACIAL DEPOSITS OR TO GLACIAL INFLUENCE

It has already been pointed out that in Minnesota all of the peat deposits lie upon glacial drift, or upon modified drift. In the driftless area in the southeast corner of the state there is no peat. At least 95 per cent of the peat deposits in Minnesota of commercial value lie north of Minneapolis and St. Paul. There are only two important types of glacial drift within the area of the great peat deposits of this region, (1) the *young red drift*, in eastern Minnesota, and (2) the *young gray drift*,[46] in the western, central, and southern parts. Both belong to the youngest, or Wisconsin, stage of Pleistocene glaciation. These drift mantles represent the last material carried in by the continental ice sheet. Other drift deposits underlie the Wisconsin drift at places, but these older deposits do not outcrop within the area containing the principal peat bogs. The greater part of the peaty area consists of water-sorted glacial material which formed the bed of Lake Agassiz.

With the exception of a small area in the northeastern part of Koochiching County, the entire bed of glacial Lake Agassiz rests upon the calcareous gray drift. The contact between the red and the gray drift sheets in northern Minnesota is shown on the large map accompanying this report (Plate I). From an inspection of this map it will be seen that the peat is not confined to any one formation, but occurs in large quantities over areas of red as well as gray drift. The largest deposits, however, are found in the bed of Lake Agassiz resting upon the gray drift. This fact is not due to any direct influence which the drift had upon the accumulation of peat, but rather to the topographic conditions in the old lake bed. It is quite probable that the peat would have formed in the lake bed if it had been on red drift instead of the gray.

One of the most interesting features in connection with the influence of glaciation upon peat formation, is the existence of inter-glacial peat beds. These are thin and mixed with much soil. The best exposure of such a bed was to be seen several years ago in the north bank of the Hull-Rust Pit of the Oliver Iron Mining Company at Hibbing. The peaty layer was about five feet thick, and occurred at the contact of the

[46] Leverett and Purssell, *op. cit.* p. 32.

old gray, or Kansan, and the Wisconsin drifts. The peat was overlain at the point of exposure by about 30 feet of stony drift of Wisconsin age.[47]

Another occurrence of a buried bed of peaty material was observed just west of the city limits of Minneapolis in a cut near Browndale station along the tracks of the electric railroad to Minnetonka. The accompanying photograph (Plate IX A) shows the outcrop of the peaty layer which appears as a dark, thin line about half way up the bank. The material is not peat, but is a buried turf or sod. The lower part of a buried tree stump may be plainly seen, extending up from this turfy layer, and the roots of the tree extend out to the right and left into the turf. Professor H. F. Bergman, who examined the wood, roots, and bark of this ancient stump, identified it as an oak. This layer of turf or sod is not an inter-glacial deposit but is very much more recent. The material both above and below it, although of glacial origin, shows distinct signs of stratification. It is probable that the old surface became buried by wash from some stream at a time when the present topography, which has been modified by post-glacial erosion, was in the process of development.

RELATION OF SOIL AND SOIL WATERS TO FORMATION OF PEAT IN MINNESOTA

From the preceding discussion it is apparent that if any evidence exists bearing upon a relationship between the character of the soil and the formation of peat in Minnesota it is to be found in a study of the different types of glacial drift. It was thought at first, because of the occurrence of the largest and deepest bogs on surfaces composed of material from the gray drift, that this material may have played an important part in the formation of the peat. The gray drift is composed largely of material brought down by the ice from the limestone and shale areas in Manitoba. The red drift is a more stony mass composed largely of material from the erosion of volcanic and hard crystalline rocks, which are characteristic of the northeastern part of Minnesota and southern Ontario. Because of the great difference in the rocks composing the two drifts, their chemical properties also are different. The gray drift is very calcareous, or limey, while the soil from the red drift is lacking in lime. The ground waters supplied by the two drift sheets also show the same differences as do the soils. These facts at first seemed to suggest that the chemical properties of the soils in northern Minnesota had a marked influence upon the origin of the peat. Recent mapping of the boundaries of the two drift sheets as well as the boundary, or shore line, of glacial Lake Agassiz by Leverett and Sardeson[48] has made available much additional data bearing upon this problem.

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[47] F. Leverett, written communication. 1915.

[48] Frank Leverett and U. G. Purssell, *op. cit.*

A. BURIED TREE STUMP, WITH ROOTS IN BURIED, PEATY TURF BED NEAR MINNEAPOLIS. THE HAND RESTS UPON THIS TURF BED WHICH CAN BE SEEN AS A THIN, DARK, HORIZONTAL LINE.
PHOTO BY DIETRICKSON

B. OUTCROP OF MARL BED, IN A SHALLOW PEAT BOG NEAR STARBUCK, POPE COUNTY

The accompanying map (Plate I) shows the location of all the important peat bogs in northern Minnesota as well as the boundaries of the drift sheets, and of the bed of Lake Agassiz. Inspection of this map will show that there are many smaller peat bogs located in the red drift outside the limits of the lake bed. In some instances, the boundary between the red and gray drifts passes through the center of a peat bog. Several typical bogs where these conditions obtain were studied and the peat was found to be uniform in character and thickness over both red and gray drift. For these reasons it is concluded that in northern Minnesota the character of the soil has had little influence in determining the location or quantity of the peat accumulation.

In southern Minnesota the evidence supports the conclusion just stated. With the exception of a lobe of old gray drift in the southeast corner of the state, and a small area of young red drift and old red drift in Washington, Ramsey, and Dakota counties, all the drift belongs to the same young gray sheet, which covers most of northern Minnesota. The majority of the southern peat bogs lie within the area of the young gray drift, but this is because most of southern Minnesota is covered with drift of this type. There are a number of peat bogs in Washington and Ramsey counties which lie upon the red drift, and if the latter had a wider distribution it would probably contain as many peat bogs as the gray.

The effect of the soils upon the purity of the peat is noticeable in some places. Glacial till or loose materials of a similar nature are more apt to make muddy the streams flowing into basins, and in that manner contaminate the peat with mineral matter, and raise the per cent of ash.

RELATION OF MARL BEDS TO PEAT DEPOSITS IN MINNESOTA

In several localities in central and northern Minnesota, notably in Crow Wing, Douglas, Itasca, Koochiching, Hennepin, and Clearwater counties, some of the peat bogs were found to be underlain by marl beds. Marl deposits in the beds of existing lakes are of frequent occurrence in some of the north central counties. They have been formed by the precipitation of lime carbonate from solution in the lake waters through the agency of the *Chara* plants (stoneworts) which abound in these lakes. Marl beds beneath peat bogs have a similar origin. This is shown by (1) the occurrence of the marl at the bottom of the deeper basin-shaped bogs; (2) the occurrence of the remains of chara imbedded in the marl, and in the transition zone between the marl and the overlying peat; (3) the occurrence of innumerable fresh water shells (chiefly snail shells) throughout the marl, and in the bottom layers of the overlying peat; (4) the occurrence of the typical "pond peat" of greenish or yellowish color, composed chiefly of pond weeds and other aquatic plants, immediately overlying the marl. Davis has shown in his paper on the marls of Michigan,[49] that these deposits are formed only in lakes and ponds and the large pure marl deposits are always the result of the influence of *Chara* or stoneworts.

This occurrence of marl and peat in the same bog is conclusive evidence that those deposits in which such an association exists represent filled lakes or ponds. The change from marl to peat indicates that at a certain time in the history of the lake conditions were brought about unfavorable to the growth of *Chara*, and favorable to other plants. In a few instances the evidence indicated that the original lake became completely filled with marl, or filled to within a foot or two of the surface before peat began to form. In such a bog the peat is composed chiefly of sphagnum and non-aquatic plants, and is a built-up deposit. Even in the filled lakes, the upper portion of the peat has been built up above the old water level of the lake by successive layers of sedges and sphagnum. The present surface of some of these peat bogs is 10 to 15 feet higher than the original water level of the lake. One of these marl beds, occurring in a shallow peat meadow near Starbuck, Pope County, is shown in Plate IX, B.

RATE OF PEAT FORMATION

Reliable data relative to the rate of peat formation in Minnesota are almost impossible to secure. There are several reasons why this is so. In the first place the rate varies greatly even in the same bog. It is probable that in every large bog in the state the rate of peat accumulation has changed from time to time since the beginning of the deposit. From evidence available from a study of those deposits which are in actual process of formation to-day, a fairly good idea may be gained of the history of the large deposits which seem to have already attained their maximum development. Observations show that the rate of peat formation in lakes and ponds is slower than in deposits of sphagnum moss built up on flat undrained areas. Dana[50] states that the rate of growth varies with the amount of vegetation, moisture, and other conditions; and he gives as a maximum one foot of peat in five or ten years.

Since all of the Minnesota bogs are of post-glacial age, we may reckon their starting point as the close of the Glacial Period. In the deposits of the filled-lake type, the rate of peat accumulation was probably slow at first. Considerable time was required for the peat-forming plants to attain their full development. With the increase of swamp and aquatic vegetation, the rate of peat formation undoubtedly was in-

[49] Charles A. Davis, *Michigan Geological Survey* 8. 1900-1903.
[50] James D. Dana, Manual of Geology 4th ed. p. 154. 1895.

creased. This increase probably continued until the rate reached its maximum, which corresponded, in the main, with the maximum development of peat-forming vegetation. Any periods of drought, or other climatic changes would tend either to check or speed up the rate at which peat would form. After the condition of maximum vegetation was attained, the rate either remained constant or gradually decreased. The deposits, as they exist to-day, comprise bogs in all stages of development.

In the case of built-up peat deposits, that is, deposits formed on flat, wet land surfaces by successive layers of the remains of plants which die annually, the rate of peat accumulation was probably rapid from the start. In such areas the first vegetation, after the recession of the ice, probably developed more quickly than that in or around lakes and ponds. Furthermore, sphagnum (peat moss), soon made its appearance in this environment, and with its rapid development the rate of peat formation was greatly increased; for sphagnum is the most valuable of all peat-forming plants, and a growth of this moss of 12 to 18 inches per year is not uncommon. This does not mean that 12 to 18 inches of peat was formed each year, because each foot of thoroughly decomposed, compacted peat represents many feet of loose, fibrous, dead moss.

A second reason why it is not possible to get accurate data on the rate of peat formation is the fact that a peat deposit may decrease in thickness during a period of drought, or by a lowering of the water level in the bog through some other cause. This permits the entrance of air and decay-producing organisms into the peat, which blacken it, reduce its bulk, and lower the surface.

The third cause for the uncertainty of data bearing on the rate of formation is the fact that many of the Minnesota bogs have been burned and then rebuilt. In some of the deposits there is evidence of several burnings, as shown by alternate layers of fresh and charred peat.

A fourth factor is the destruction of peat deposits by the rising waters of lakes and by wave action. The peat bogs bordering the south shore of Lake of the Woods, in Roseau and Beltrami counties, have undergone changes in elevation due to these causes within the past twenty years, and possibly the peat has been eroded away and rebuilt at other more remote times in the past. According to Professor Adolph F. Meyer of the University of Minnesota, Lake of the Woods since 1888 has been maintained at a stage which averaged about 3 feet higher than its elevation previous to that date, or 3 feet higher than it would have been during that time under normal conditions, had the outflow not been controlled. In a number of places around the Lake of the Woods the peat is from 2 to 4 feet thick over extensive areas near the present shore line. The peat beds decrease in thickness away from the shore line, and disappear at a distance of approximately 1 mile inland. In some places, however, the peat is thicker and extends 3 or 4 miles back from the lake shore. The peat has become loosened from the sub-soil in many places, due to the high-water level of the lake, and is now floating, so that it rises and falls with the level of the lake. In other places, the waves have torn the floating mat apart, and the peat has become disintegrated and been scattered over the lake bottom, the finer material remaining suspended in sufficient quantities to give the waters of the lake a distinctive color and odor for miles out from shore. In still other places the waves have piled up this disintegrated peat in a long ridge or barrier parallel to the shore. This wave erosion of peat beds was observed by the writer on a very much smaller scale in several other lakes in northern Minnesota.

Still another difficulty in the way of satisfactory evidence is the absence of any observations extending over sufficient periods of time to render them trustworthy. Certainly peat deposits of commercial size and depth require considerable time for their development. The subject has attracted interest in this country only during recent years and no careful observations or records have been made. Even in the young bogs now forming, the rate of growth is so slow that it is not possible to gage it by any means other than careful leveling each year, or at regular intervals of several years. Were this method of measurement attempted by competent observers, and continued over a period of years, it is certain that more accurate results would be obtained than by any other method.

Most of the settlers who have lived in the regions where peat occurs can not recognize any apparent change in the bogs within the period of their residence. Assuming that the growth of the peat dates from the close of the Glacial Period, which various geologists reckon from 10,000 to 30,000 years ago, it is evident that most of the bogs have developed very slowly, or else they attained their maximum depth in a shorter time and have remained at approximately the same level every since.

Taking the shorter interval of 10,000 years as the time which has elapsed since the retreat of the ice, and taking 12 feet as the average thickness of some of the largest bogs, and assuming the accumulation to have been uninterrupted by fires or drought, we get a growth of .014 of an inch of peat as the average annual rate of accumulation.

DEPTH OF ACCUMULATION

The limitation in vertical thickness of all peat bogs is determined by the form of surface upon which the bog develops, as pointed out by

A. SMALL MUSKEG OF THE FILLED-LAKE TYPE. THE PEAT IS 25 FEET THICK IN THIS BOG, WHICH FILLS A DEEP DEPRESSION BETWEEN MORAINAL HILLS, NEAR COLERAINE, ITASCA COUNTY

B. OPEN BOG OF THE FILLED-LAKE TYPE. THE SMALL REMNANT OF THE LAKE MAY STILL BE SEEN IN THE CENTER OF THE BOG. NEAR CASS LAKE, CASS COUNTY

Shaler.[51] In Minnesota, deposits formed by the filling in of lake basins are deeper as a rule than those formed on low, flat, swampy surfaces. On the other hand, in many basins the deposition of vegetation has, for some cause, been arrested, and the process of peat accumulation stopped. Under such conditions, the peat in the built-up deposits might be of greater thickness than in lake basins.

There is a large variation in the thickness of the peat bogs throughout the state. Those in the southern portion are, in general, much more shallow than those in the north. In these southern deposits the peat varies in thickness from merely a thin peaty sod of a few inches, up to 18 feet. Only two or three localities were found south of the Twin Cities, where the latter depth obtained. The average thickness for southern Minnesota is only 4 or 5 feet. In the north, thicknesses of 18 feet are common in the filled-lake deposits, and many of these attain a depth of 20 to 25 feet in the center of the bog. The maximum thickness recorded is 63 feet in St. Louis County, near Central Lakes Station, on the Duluth, Winnipeg, and Pacific Railroad. This bog, which is described on page 234, is crossed by the railroad and much trouble has been experienced in keeping the tracks in condition, where they overlie the deeper portions of the deposit. A series of soundings was made by the company's engineers, who have kindly supplied the resulting data which are given elsewhere in this report. (See Figure 10, page 235.)

At several other localities, notably the Corona Bog, at Corona, Carlton County, the deposits were so deep in the center that bottom was not reached with a 25-foot Davis sounding rod. These bogs are all of the filled-lake type.

The average depth of peat over the great built-up deposits occupying portions of the bed of Lake Agassiz in north central Minnesota is about 7 to 9 feet. The thickness increases to 18 or 20 feet in many places, which apparently overlie depressions and hollows in the former lake bed.

In northwestern Minnesota, in Marshall and Roseau counties, some of the largest unbroken areas of peat in the state occur, but these are usually shallow. The average depth of peat over this region does not exceed 4 or 5 feet. Most of this region has been burned over, which probably accounts for the shallow depths.

In northeastern Minnesota the peat bogs are chiefly of the filled-lake type. In St. Louis County and the western part of Lake County, the thickness is variable. The deepest portion of the deposit is usually near the center, and the thickness gradually diminishes as one approaches the edge of the bog, which corresponds with the rim of the basin in which the peat accumulated. The average depth attained in the center of these bogs is about 12 to 15 feet.

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[51] N. S. Shaler, *op. cit.* p. 262.

CLASSIFICATIONS OF MINNESOTA PEAT DEPOSITS

The peat deposits of Minnesota may be classified in the following ways:

1. Classification based on type of land surface upon which the peat formed
2. Classification based on types of plants composing the peat
3. Classification according to geographic distribution
4. Classification based on vegetation growing on the bogs
5. Classification based on physical characteristics of the peat
6. Classification based on uses for which the peat is adapted.

CLASSIFICATION BASED ON TYPE OF LAND SURFACE UPON WHICH THE PEAT FORMED

This is believed to be the most logical basis for classifying peat deposits, and hence will be discussed at more length than others. Under this scheme the peat bogs fall into the following groups:

1. Deposits which represent filled lakes or ponds (Figures A and B, Plate X).
2. Deposits which represent accumulations on built-up moist depressions, or flat undrained areas (Plate XI).
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 types 1 or 2 in appearance, and their true nature may only be ascertained by soundings.

The origin of these various types of peat has already been described. The deposits of group 1, which represent filled lakes or ponds, constitute the majority of the smaller bogs of the state. They are especially well developed in the central and northeastern parts, but are not uncommon in southern Minnesota. Scattered over the large built-up muskegs of the north, are numerous areas in which the peat is of a different character from that of the main part of the swamp, and which shows by the plant remains that it has clearly originated in lakes or ponds. The aquatic and other vegetation as preserved in the peat, serve as an unfailing means of determining the conditions under which it accumulated. Where sphagnum is present in the lower part of the deposit, even in relatively small quantities, it is conclusive evidence that the peat was not formed in lakes, since this moss does not thrive in open water. Although rare instances have been observed in other localities, where sphagnum was growing on the surface of pools and ponds, no such occurrence was seen in Minnesota.

It is estimated that there are about 10,000 lakes in Minnesota. Practically all of these were formed at the close of the Glacial Period, as were the hundreds of lakes which are now filled with peat. The

PLATE XI

OPEN BOG OF THE BUILT-UP TYPE, FORMED ON A FLAT, UNDRAINED SURFACE, WHICH WAS ONCE A PORTION OF GLACIAL LAKE AGASSIZ. BLACK PEAT IS SHOWN ON SPOIL BANK AT SIDE OF DRAINAGE DITCH. BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

question will naturally arise as to why some of these lakes became peat filled, while others of the same age and origin are still open bodies of water without a trace of peat. As pointed out by Shaler,[52] peat will form in lakes only when there is but little wave action on the shores; or when the shores are fringed with pond-lilies which protect the peat from wave erosion.

The deposits which represent built-up moist depressions or flat undrained areas are, on the other hand, usually composed chiefly of sphagnum or sedge remains. To this type of deposit belong the largest bogs in Minnesota. They are especially well developed in the northern part of the state in Roseau, Marshall, Beltrami, and Koochiching counties, and the southwestern part of St. Louis County. Two of these big open bogs are shown on Plate XII. The bogs are not all sphagnum peat. In Roseau and Marshall counties, the peat contains very little sphagnum, but is composed chiefly of the remains of grasses and sedges. These deposits are shallow, however. The largest and deepest built-up bogs are in Beltrami and Koochiching counties. There the peat is often composed almost entirely of sphagnum from top to bottom. In the deeper built-up bogs of this region the bottom 4 or 5 feet of peat are frequently composed of grass and sedge remains, which are covered with 5 or 6 feet of sphagnum peat. The average depth of these built-up deposits in the north central region is 7 to 9 feet.

The deposits which represent combinations of lake and sphagnum peat (type 3 in this classification) are frequently found in northern and central Minnesota but never in the south. In these bogs the contact between the upper zone of sphagnum and the lower zone consisting of aquatic plants, sedges, cattails, grasses, etc., is usually well defined. This contact represents the former water level of the lake or pond. When the basin becomes filled with peat to this level, a new type of vegetation develops on top of the sedge mat, and sphagnum becomes a prominent factor in the history of the bog. From this point on, the peat is built up by annual accumulations of layers of dead sphagnum moss. Accompanying this peat moss there usually appears a prominent growth of heaths, so common to the muskegs of northern Minnesota, and these shrubs, as they die each year, add their substance to the growth of the deposit. In this way, the surface of the bog is gradually built up until it reaches a level often 8 or 10 feet higher than the original level of the lake. Such deposits are common in the northern and central portions of the state, but none were observed in the south. In the south, there are bogs which belong to the same general type of deposits, built up from filled lakes, but the upper portions of these southern bogs are composed chiefly of grasses and sedges instead of sphagnum and heaths.

[52] N. S. Shaler, Origin, Distribution, and Commercial Value of Peat Deposits. U. S. Geological Survey *16th An. Report* part IV p. 305.

CLASSIFICATION BASED ON TYPES OF PLANTS COMPOSING THE PEAT

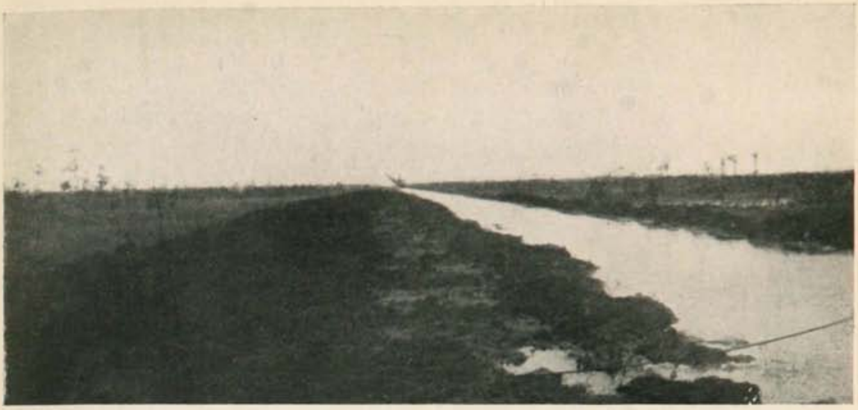
A second method of classifying the Minnesota bogs is based on their plant constituents. We may recognize the following types:

1. Sphagnum-Heath Peat. This type includes all bogs in which the peat is composed essentially of sphagnum moss from top to bottom. As shown in the foregoing classification it includes only deposits which were built up on flat, undrained areas. The bogs of this type occur chiefly in the north and especially within the area formerly occupied by glacial Lake Agassiz.

2. Sedge-Grass Peat. Bogs which contain no moss, but which are composed chiefly of the remains of various sedges (mostly *Carex*, of which many species were recognized) and grasses; with subordinate remains of reed-grass, cattails, bulrushes, and a few shrubs and weeds. Such deposits are, like sphagnum peat, the result of accumulations on wet, flat areas, and were built up by successive generations of dead vegetation. As the surface of the deposit was elevated, the ground water rose with it so that the entire mass was kept saturated, and thus decay was prevented. Bogs of this class usually appear as meadows, or "wire-grass" marshes, as they are often called by the farmers. The term "meadow peat" is sometimes applied to the material. They are common in central and southern Minnesota, but rarely occur in the north. The peat is of good quality, usually well decomposed, and often 7 or 8 feet deep.

3. Pond Peat. Deposits consisting essentially of pondweeds (*potamogeton*) and other aquatic plants such as pond-lilies, lake bulrushes, amphibious sedges, etc. Such deposits are rarely found in Minnesota except under water, where the lakes in which they are forming have not had time to become completely filled. As soon as the lake does become filled, the sedges from the edge of the water quickly spread towards the center of the deposit, and soon monopolize the entire surface, forming a heavy sedge mat which obscures the nature of the peat below. Pond peat is in process of formation in all parts of the state where peat occurs. It is often found to underlie deposits which on top are composed of sphagnum or sedge-grass peat.

4. Sphagnum-Pond Peat. Deposits of pond peat formed in lakes and ponds which have become covered with sphagnum peat after the lake was filled. They represent a combination of types 1 and 3. This class includes all of the deepest bogs of the north. In fact, most of the deep deposits of the state are of this type. They are frequently found in the center of large, built-up deposits of sphagnum-heath peat such as the big muskegs of Beltrami, Koochiching, and St. Louis counties. Since there is little sphagnum in southern Minnesota, they are practically unknown in that region.



A. BIG, OPEN, SPHAGNUM-HEATH-TAMARACK BOG OF THE BUILT-UP TYPE. NOTE DREDGE AT WORK IN THE DISTANCE. BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

B. BUILT-UP BOG, COVERED WITH SCRUB TAMARACK, BUT SOMEWHAT OPEN. NOTE THE SMOOTH, FLAT SURFACE. BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

5. Sphagnum-Sedge Peat. Bogs which consist of layers of sphagnum of variable thickness overlying peat which is made up chiefly of sedges. In northern and central Minnesota such bogs are not uncommon. They represent deposits of the built-up type which evidently originated as marshes which were not permanently under water but which were too wet, at first, for sphagnum to thrive.

6. Sedge-Pond Peat. Deposits of pond peat, formed under water, which have later become covered with a sedge mat (as mentioned under type 3) which has gradually built up the level of the surface of the bog. In some cases this sedge mat, with which are associated grasses, cattails, reeds, shrubs, etc., attains a thickness of 10 to 12 feet. This type of bog is most frequently found in central and southern Minnesota.

CLASSIFICATION ACCORDING TO GEOGRAPHIC DISTRIBUTION

The peat deposits of Minnesota fall into three more or less distinct groups: (1) deposits in northern Minnesota; (2) deposits in central Minnesota; and (3) deposits in southern Minnesota.

This grouping is really based on more than mere geographic distribution, for the peat in the northern, central, and southern parts of the state shows differences as to origin, character, and composition; and the deposits in each group occur in an environment characteristic for that region.

Northern Minnesota.—As stated before, the largest, deepest, and most important deposits occur in the "muskeg" swamps and open bogs and marshes of the northern portion. The peat in these muskegs is formed chiefly of sphagnum, or peat moss, and some of the largest bogs, embracing hundreds of square miles, are built up almost entirely by successive layers of this moss. Scattered over these immense swamps of sphagnum peat are smaller areas where the peat is much deeper and of a different character below the upper layers. These deep portions of the bogs represent filled lakes and the peat shows a different origin and structure from the prevailing sphagnum type of the north. In these filled lakes the peat is formed of sphagnum only in the upper part of the deposit and down as far as the old water level of the original lake. Below that depth, the peat consists of the remains of sedges, grasses, rushes, and pondweeds so characteristic of all deposits which represent filled lakes.

The sphagnum peat of northern Minnesota is by far the most abundant and is of better grade than the other varieties. It is probable that at least three fourths of the area covered by peat in this region was originally a flat, undrained, land surface, left in that condition by the gradual draining of glacial Lake Agassiz.

In addition to the peat bogs of the type just described, there are in the western part of the northern region numerous examples of deposits which contain little or no sphagnum, although the peat was formed in the same way as the built-up sphagnum bogs. These deposits are composed mostly of sedges, grasses, cattails, rushes, etc., and probably accumulated in marshes which were too wet for sphagnum to grow. The name sedge-grass bog has been applied to deposits of this type. They are especially well developed in Roseau, Marshall, and western Beltrami counties. Many of the bogs are large, and some cover 50 square miles. The peat is usually shallow, the average depth being not more than 4 feet.

The third type of bog common to the north includes the filled-lake deposits, which are isolated and not connected with built-up sphagnum bogs. The peat in these filled lakes is composed chiefly of sedge remains, although the soft greenish peat, characteristic of that formed from aquatic plants, such as pondweeds, pond-lilies, etc., is often found underlying the upper sedge layers. These bogs are usually small and occur as green meadows occupying depressions in regions of morainal topography. Hence they are often called meadow bogs. The peat is sometimes of considerable depth toward the center of the bogs, but the thickness rapidly becomes less as the rim of the basin is approached. This type of bog is most frequently met with in the southern part of the northern province, especially in Cass, Hubbard, Clearwater, Aitkin, Crow Wing, Becker, and Otter Tail counties.

Central Minnesota.—The peat deposits of central Minnesota have, in part, the same origin and history as those just described. However, sphagnum moss does not grow, except in rare isolated occurrences, south of an east-west line drawn approximately through the cities of Minneapolis and St. Paul. Hence north of this latitude, the peat is of the same general type as that of northern Minnesota; and south of it the peat is of different type; while along a belt twenty-five to thirty miles wide, near the dividing line, there are numerous deposits of each type and sometimes deposits which represent combinations of both. The peat bogs of central Minnesota are not nearly so large as those of the north, but are much larger than those south of this region. The best and largest deposits lie in Anoka, Ramsey, Wright, Hennepin, Stearns, Sherburne, Isanti, Washington, Chisago, Mille Lacs, and Douglas counties.

The tamarack swamps or muskegs of the central part of the state are numerous, but are very small—usually containing less than 100 acres. On the other hand, there are some very extensive open sedge-grass bogs, called "wire-grass" marshes, scattered throughout central Minnesota. One of the largest of these occurs only about twelve miles north of Minneapolis and St. Paul, in Anoka County, and contains good fuel peat with an average depth of 6 to 7 feet over many thousands of acres.

Southern Minnesota.—The peat of southern Minnesota is always found in open, treeless meadows or marshes, and is composed chiefly of sedges, grasses, cattails, rushes, and other plants which are common to such an environment. The peat beds represent in part filled lakes and ponds, and partly built-up deposits on low undrained areas. They occupy the low land around the shores of lakes, or along river valleys, or merely low, undrained depressions in the drift. They are usually very small in area and shallow in depth compared with the peat bogs of the north, but nevertheless numerous deposits of future commercial value exist, especially in Blue Earth, Nicollet, Le Sueur, Rice, and Freeborn counties.

CLASSIFICATION BASED ON VEGETATION GROWING ON THE BOG

This method of classifying the peat bogs in Minnesota is somewhat different from the method already outlined, in which the deposits are grouped according to the kinds of plants which compose the peat, because in many instances the prevailing types of vegetation now found growing on the bogs are quite different from those which formerly grew there, and which now form the bulk of the peat deposit. Upon this basis, the following types of bogs may be recognized:

1. Tamarack swamps
2. Spruce swamps
3. Tamarack-spruce swamps } Muskegs
4. Sphagnum-heath bogs
5. Cedar swamps
6. Sedge-bogs
7. Grass-sedge bogs or meadows.

Sphagnum moss may be found in each of the seven kinds of peat bogs, but it is usually present in only small amounts in the cedar swamps, and is often entirely absent in the sedge and grass bogs. In the tamarack and spruce bogs, the sphagnum moss is usually the principal peat former, although it may be less conspicuous than the trees. In the sphagnum heath bogs, the moss is, of course, the dominant plant.

Tamarack swamps.—In northern and central Minnesota most of the peat deposits are covered with a growth of coniferous trees of which the tamarack (*Larex laricina*) is the commonest. These trees are always relatively small when the peat is of any considerable thickness, and the growth is usually scattered. But some large swamps occur in which the growth of trees is so dense as to render them difficult of access. Mixed with the tamaracks, black spruce are often prominent, and in some cases, a considerable number of cedars are present. This name, tamarack swamp, is intended to apply only to those areas where the tamarack is the dominating tree now growing on the surface. Plate VIII shows two typical tamarack swamps in northern Minnesota.

Spruce swamps.—The black or swamp spruce (*Picea mariana*) is, next to the tamarack, the most abundant peat swamp tree in northern and central Minnesota. Typical spruce swamps are shown on Plate XIII. The bogs in which this tree is prominent seem to differ in no other respects from the tamarack swamps. Some observers have inclined to the belief that the presence of spruce as the dominant vegetation indicated shallower peat deposits than those in which tamaracks prevailed, but field studies in Minnesota have failed to show any such relationship. In fact, in some of the largest and deepest bogs of northern Minnesota, tamaracks and spruce trees seem to be present in about equal numbers, without any tendency towards a "spotty" or "segregated" occurrence of either type of tree.

Tamarack-spruce swamps.—Swamps in which tamaracks and spruce trees are present in approximately equal numbers are rather common in the northern region, and to this type of peat deposit the name tamarack-spruce swamp is applied. As stated, the swamps differ in no other characteristic from those in which but one type of tree is present, and the depth of the peat, which usually consists chiefly of sphagnum, especially in the upper 8 or 10 feet of the deposit, seems to bear no relation to the relative abundance of either tree. Views of swamps of this type are shown on Plate XIV.

Sphagnum-heath bogs.—Scattered over these tamarack and spruce swamps are numerous treeless areas upon which sphagnum moss, heath shrubs, blueberry and wild cranberry plants, form the principal vegetation. These open areas usually indicate an increase in the depth of the peat, and, with a few exceptions, soundings have proved that such areas overlie basin-shaped depressions which probably represent filled lakes or ponds. Plate XV shows two typical open heath bogs of this type. There are also, in northern and central Minnesota, hundreds of smaller bogs of this type which occur as complete units and which are not merely portions of large tamarack or spruce swamps.

These tamarack and spruce swamps with the open sphagnum-heath areas which they contain are called muskegs in Minnesota, Wisconsin, Michigan, and eastern Canada. "Muskeg" is an Indian word, which means "swamp." However, the term, as now applied, is restricted to those swamps which are characterized by forests of scrub tamarack and black spruce trees with an undergrowth of many low heath shrubs, growing upon a dense, thick mat of sphagnum moss.

Cedar swamps.—In northern Minnesota, some of the swamps are forested with a heavy growth of white cedar, and frequently cedars are associated with either spruce or tamarack, or both. These cedar swamps, however, are not typical muskegs, and the peat in them is usually shallower, contains more woody fibre, and little or no sphagnum.

A. A TYPICAL SPRUCE SWAMP, LOOKING ALONG NEWLY CONSTRUCTED STATE ROAD NO. 6. BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

B. ANOTHER VIEW OF SAME SPRUCE SWAMP AS SHOWN IN *A* BEFORE COMPLETION OF ROAD. BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

Sedge bogs.—A very different type of bog found chiefly in the northwestern and central portions of the state is the open sedge bog. As the name implies, the deposits are covered with a vegetation consisting principally of sedges, of which the species known as *Carex* is by far the most abundant. Associated with the sedges are grasses, cattails, rushes, and various small mosses, but sphagnum is rarely present. Bogs of this type have originated as filled lakes and also as built-up deposits, but they are, as a class, shallower than those described above. Figure A, Plate XVI, shows a sedge bog.

Grass-sedge bogs or meadows.—Grass-sedge bogs, or meadows, are numerous in southern Minnesota, and there are some in central Minnesota. They differ from the sedge bogs chiefly in the relative increase in the amount of grasses, reeds, cattails, etc., at the expense of the sedges. Associated with these plants there often occur low shrubs such as willows and alders. Weeds and ferns are also sometimes present. The peat is usually shallow, and some of it is mixed with considerable mineral matter, which gives to the material more of the properties of a muck than a true peat. This is, however, the exception rather than the rule, and the majority of such bogs contain good fuel peat, although not always of workable depth. Many of these bogs are used for pasture meadows, and, in some, the marsh or "wire grass" (as it is called) is cut for hay.

CLASSIFICATION BASED ON PHYSICAL CHARACTERISTICS OF THE PEAT

This is not considered to be a practicable means of classification of Minnesota peats because it is often difficult to determine the proper place in which a given peat deposit belongs in such a scheme. This is chiefly because the physical properties of the peat change in the same bog at different depths. Disregarding these differences, and considering the average quality of the peat in a given deposit, the following varieties are noted:

1. Fibrous or mossy peat
2. Well decomposed structureless peat
3. Woody peat
4. Soily peat or muck

Fibrous or mossy peat.—Most of the peat of Minnesota belongs to this class, and in the northern part of the state, where the peat consists chiefly of remains of sphagnum moss and sedges, practically all of it is fibrous. The exceptions to this rule are found in the lower portions of the deeper bogs which represent filled lakes. But even in such deposits, the upper half of the accumulation is nearly always fibrous. The built-up deposits, consisting of moss from top to bottom, and the big shallow sedge bogs of the northwest are composed of mossy or fibrous material throughout. In the south, the peat is also fibrous, although the fibre structure is quite different from that of the sphagnum peat.

Well decomposed structureless peat.—Below depths of 8 to 10 feet in the deep, filled-lake deposits of the north, the peat usually changes in texture and structure from fibrous to a soft, well decomposed, structureless mass in which the plant remains have undergone more decomposition, and have lost their original shape and size. The peat at these lower depths carries also a considerably higher per cent of water, which aids in the separation of the decomposed fragments of the plant tissue. A third reason for this lack of structure in filled-lake deposits is the fact that the peat has originated from aquatic plants which are softer and disintegrate more readily than the tougher and more hardy sphagnum moss and heaths.

Woody peat.—In many of the tamarack, spruce, and cedar swamps, the peat is full of dead tree stumps, limbs, and roots which have accumulated for hundreds of years. These various trees have died in great numbers at certain periods in the history of some of the bogs, when the moisture content of the peat at the top of the bog became either too high or too low to support the particular type of vegetation then growing upon it. The roots and stumps of these dead trees were left several feet below the surface of the bog and hence were protected from the air. Thus they have been preserved for long periods. Numerous examples were observed during the course of the field investigations for this report, where hard, well preserved stumps and roots of tamarack and spruce trees were present in great numbers at a depth of from 10 to 25 feet below the surface of the bog. When the slow rate at which this peat has accumulated is taken into consideration, the long periods of time required for a stump to become covered with 25 feet of peat may be appreciated.

Another common way in which stumps and pieces of wood become buried in the peat bogs of northern Minnesota is by the fires which have swept over much of this northern territory from time to time. These fires can not burn the peat below the permanent water level in the bog, but they usually kill the majority of the trees growing on the surface. These fall, or are later blown over by the wind, and gradually become buried beneath new generations of mosses and other peat-forming plants, which spring up after the fire has passed.

In some of the more densely timbered swamps, the peat is so full of small fragments of partially decomposed wood, stumps, logs, sticks, bark, etc., that it is rendered unfit for use as fuel, since the ordinary peat machinery can not handle it, and the cost of sorting out the logs and roots would be prohibitive.

A TAMARACK-SPRUCE SWAMP, SHOWING SCATTERED GROWTH OF SMALL TREES WITH INTERVENING AREAS OF OPEN HEATH BOG. NEAR DEER RIVER, ITASCA COUNTY

Soily peat or muck.—Along stream valleys, or in hollows into which streams flow, the peat is usually mixed with more mineral matter than elsewhere. This soil or mineral matter is inert and forms the ash which remains when the peat is burned for fuel. When the proportion of soil in the peat is so high as to cause it to be sticky or gritty, and to have the appearance of a heavy black loam rather than peat, the material is usually called muck. There are but few muck deposits north of Minneapolis, but in the southern counties much of the so-called peat is all muck. This is because many of the bogs and marshes of southern Minnesota occur along stream valleys where the mineral matter is washed in and mixed with the peat each year. This muck, although entirely unfit for use as fuel, makes an excellent soil for certain crops, when properly drained.

CLASSIFICATION ACCORDING TO USES FOR WHICH PEAT IS ADAPTED

The peat deposits of Minnesota may be grouped under the following heads, according to the uses for which the material is best adapted:

1. Peat for fuels
2. Peat for stable litter and packing material
3. Peat for paper stock
4. Peat for woven fabrics
5. Peat lands suitable for agricultural purposes.

This is by no means a complete list of all of the uses of Minnesota peat, for some types of peat may be used in many ways.

The various uses for which the peat deposits of the state are adapted are discussed in detail in the chapter dealing with the utilization of Minnesota peat deposits.

THE VEGETATION OF MINNESOTA SWAMPS

BY H. F. BERGMAN

The type of vegetation which finally becomes dominant in a region is determined by the climate, but the kind of vegetation within limited areas of a region is controlled by local conditions, chiefly by the amount of water in the habitat. Minnesota may be divided into three regions, viz., pine forest, deciduous forest, and prairie (see Figure 4) according to the final or climax vegetation which dominates these areas.[53] Within each region the same final stage or climax has been reached through a series of developmental stages whether starting from open water or denuded land.

A swamp is due to an excess of water in a local habitat. It may have its origin in a lake which by filling up becomes converted into a swamp or it may be the result of the flooding of an area. In either case a swamp

[53] H. F. Bergman, and H. Stallard, The Development of Climax Formations in Minnesota. *Minn. Bot. Stud.* 4: part IV. 1916.

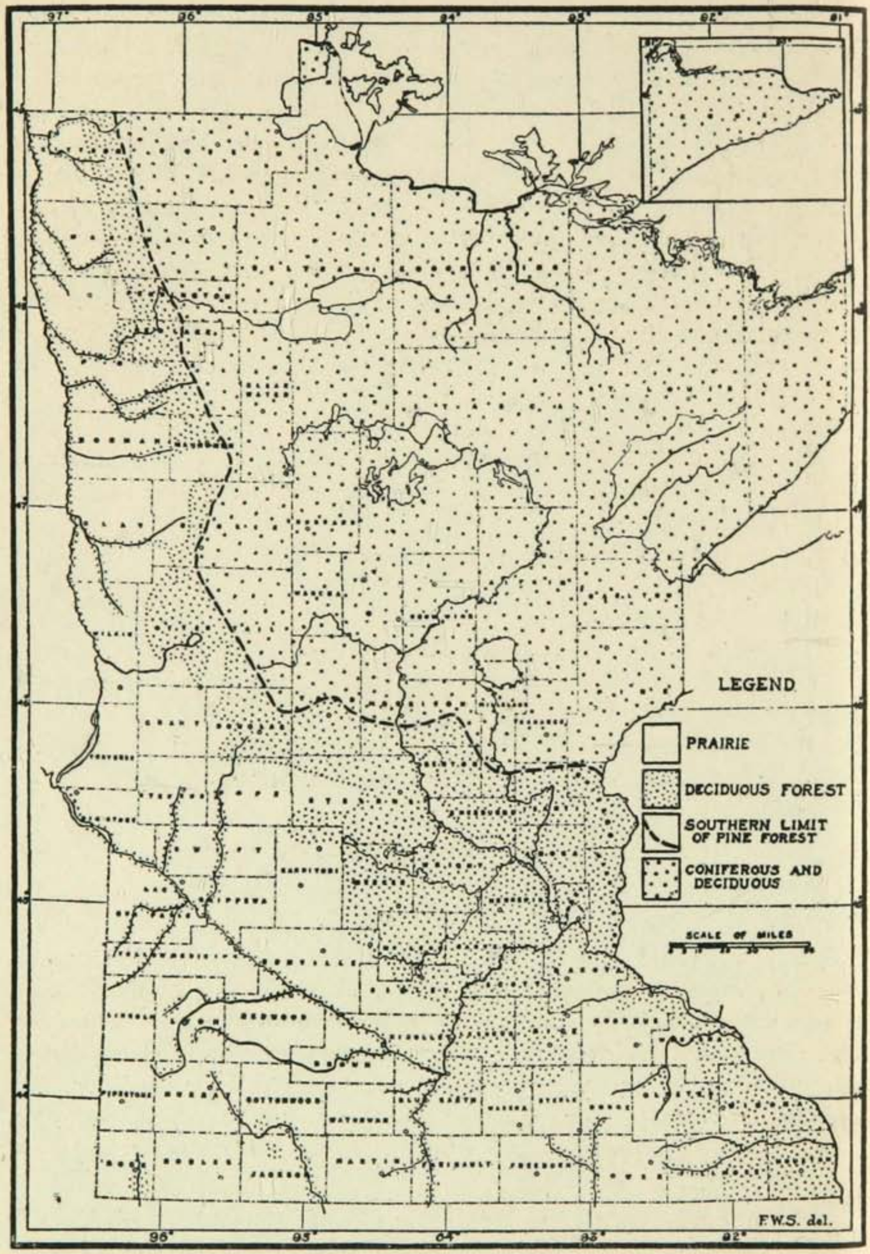


FIGURE 4. MAP OF MINNESOTA SHOWING DISTRIBUTION OF FOREST AND PRAIRIE. (AFTER MAP BY WARREN UPHAM AND FREDERIC K. BUTTERS.) THE PEAT DEPOSITS LIE CHIEFLY IN THE AREA OF CONIFEROUS FORESTS

A. OPEN HEATH AND SEDGE BOG, BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

B. SPHAGNUM-HEATH BOG WITH A FEW SCATTERED SPRUCE AND TAMARACK TREES. BENEDICT, HUBBARD COUNTY

represents a more or less permanent arrest in the development of the regional climax. If a swamp originates by the filling of a lake it is an arrested primary succession, if by the flooding of an area an arrested secondary succession, unless the flooding be to a great depth, in which case a primary succession would result.

Swamps occur in each of the climax regions and may be of such diverse character that on first consideration there seems to be no relation between the kind of vegetation in one as compared with another. This is particularly true in the comparison of a tamarack or spruce swamp with an open swamp of bog-heaths or of grass and sedge. Yet in all three a definite relation with reference to the regional climax exists. This becomes apparent by the consideration of the development of swamps.

A succession beginning in open water and culminating in a climax or earlier stage of stabilization is a hydrarch succession. This is subdivided into primary and secondary succession. A primary succession begins with the lowest stage, i.e., in open water with algae, stonewort, etc. A secondary succession may begin at any stage beyond the first or lowest, the stage at which it will begin (in hydrarch succession) being determined by the depth to which the area concerned is flooded. The successional development may be arrested at any stage which then persists indefinitely as a sub-climax.[54]

DEVELOPMENT OF SWAMPS BY PRIMARY SUCCESSION

Development of swamps by primary succession is as follows: (1) in the pine forest climax, (2) in the deciduous forest climax, and (3) in the prairie region.

IN THE PINE FOREST CLIMAX

Swamps developing by primary succession have their origin in a lake, i.e., are filled-lake swamps and go through the following developmental stages (associes):

1. Stonewort-waterweed stage (*Chara-Philotria associes*)
2. Pondweed–water-lily stage (*Potamogeton-Nymphaea associes*)
3. Rush–wild rice stage (*Scirpus-Zizania associes*)
4. Bog-meadow stage (*Carex associes*)
5. Bog-heath stage (*Andromeda-Ledum associes*)
6. Tamarack-spruce stage (*Larix-Picea associes*)
7. Balsam-birch stage
8. The pine association

1. *Stonewort-waterweed stage.*—In the process of filling a lake the first plants to become established are stonewort (*Chara sp.*), waterweed (*Philotria canadensis*) and species of water milfoil (*Myriophyllum*).

[54] F. E. Clements, Plant Succession. 1916.

Stonewort occurs in water to a depth of fifteen to twenty feet, as does also water milfoil. In water of this depth the growth is never very abundant owing to the greatly decreased intensity of the light. As the water becomes shallower, however, all the plants make a more luxuriant growth, sometimes forming a dense layer three to six feet thick. Usually stonewort does not make a very rank growth, the other species replacing it in shallower water.

In a small lake, 3 miles south of Shevlin, now in the process of filling, stonewort makes a very conspicuous zone in water from 5 to 15 feet deep. Here, stonewort forms a dense layer, coming nearly to the surface in 5 to 8 feet of water. The growth of stonewort in this lake has always been heavy as evidenced by the large accumulation of marl. A similar condition, apparently, has prevailed in Rice Lake, near Hubert, although stonewort has practically disappeared, the present vegetation consisting mostly of wild rice.

2. *Pondweed–water-lily stage.*—As a lake fills up by the deposition of dead plant remains and by the washing-in of eroded material along the shore, the invasion of species belonging to the second stage becomes possible.

The characteristic plants of this stage are riverweed (*Potamogeton sp.*), white water-lily (*Castalia odorata* and *C. tuberosa*), yellow water-lily (*Nymphaea advena*), horned pondweed (*Zannichellia palustris*), bladderwort (*Utricularia vulgaris*) and water milfoil (*Myriophyllum sp.*).

Pondweeds are the first invaders in water 5 to 10 feet deep. (See Plate XVII.) Water-lilies occur in water varying from 2 to 6 feet. Bladderwort and water milfoil grow in water from a few inches to several feet in depth. If the lake bottom is of sand or gravel none of the plants of this stage will appear, the presence of silt or decayed plant remains being essential to their establishment.

3. *Rush–wild rice stage.*—In shallow water along shore species belonging to this stage appear. The following are characteristic: larger bulrush (*Scirpus validus*), western bulrush (*Scirpus occidentalis*), wild rice (*Zizania aquatica*), reed (*Phragmites phragmites*), cattail (*Typha latifolia*).

These do not always occur together, the stage often being represented by a single species or by two or three together. (See Plate VIII.) As the filling takes place by the deposition of eroded material along the shore the plants of this stage advance farther out into the lake. When a lake is of nearly uniform depth, as it becomes filled it may be completely occupied by a single species, usually wild rice, as in Mud Lake, south of Ball Club, or in Rice Lake near Hubert.

Bulrushes and reed may become established on sandy lake bottoms which wild rice and cattail are unable to do. Where a lake-shore is subject to severe wave-action or ice-action none of the species can

A. SEDGE BOG DEVELOPED ON A BURNED MUSKEG. NOTE DEAD TAMARACK STUMPS. NEAR BEMIDJI, BELTRAMI COUNTY

B. TYPICAL GRASS-SEDGE OR "MEADOW" BOG. NEAR BEMIDJI, BELTRAMI COUNTY

become established. Reeds usually do not cover extensive areas, but are seldom entirely absent. Rushes and cattails seem to be most abundant in the prairie region. As secondary species in this stage may be mentioned:

Arrow-leaf (*Sagittaria arifolia* and *S. latifolia*), water-plantain (*Alisma plantago-aquatica*), smartweed (*Polygonum emersum* and *P. amphibium*), bur-reed (*Sparganium eurycarpum*), sweet flag (*Acorus calamus*), rush (*Scirpus americanus*), horsetail (*Equisetum fluviatile*).

Species of duckweed (*Lemna* and *Spirodela*), water milfoil, bladderwort, several kinds of pondweed and algae also occur in this stage.

4. *Bog-meadow stage.*—This is usually the first stage to which the term swamp is applied, although areas of cattail or reed which are found occasionally are also designated as swamps. The reaction of the plants of the previous stage in building up the lake shores by retaining the sedimentary material washed into the lake and also by the accumulation of decayed plant remains results in a lowering of the water level. This permits the invasion and establishment of plants of the bog-meadow stage. The lowering of the water level in a lake by drainage also makes possible the establishment of species of this stage. The following species of *Carex* are the usual dominants of this stage: water sedge (*Carex aquatilis*), bog sedge (*Carex diandra*), slender sedge (*Carex filiformis*), hairy-fruited sedge (*Carex trichocarpa*).

The following are characteristic secondary species: Long-leaved chickweed (*Alsine longifolia*), paniculate aster (*Aster paniculatus*), marsh bellflower (*Campanula aparinoides*), Bebb's sedge (*Carex bebbii*), marsh shield-fern (*Dryopteris thelypteris*), water hemlock (*Cicuta bulbifera*), small bedstraw (*Galium trifidum*), American wild mint (*Mentha canadensis*), marsh muhlenbergia (*Muhlenbergia racemosa*), tufted loosestrife (*Naumbergia thyrsiflora*), reed canary-grass (*Phalaris arundinacea*), swamp dock (*Rumex verticellatus*), marsh skullcap (*Scutellaria galericulata*).

The following species usually occur in this stage but are not present in great number: swamp milkweed (*Asclepias incarnata*), marsh marigold (*Caltha palustris*), swamp thistle (*Carduus muticus*), marsh cinquefoil (*Comarum palustre*), trumpetweed (*Eupatorium purpureum*), willow-herb (*Epilobium lineare*), horsetail (*Equisetum fluviatile*), cotton-grass (*Eriophorum polystachyon*), large blue flag (*Iris versicolor*), marsh vetchling (*Lathyrus palustris*), buck-bean (*Menyanthes trifoliata*), water smartweed (*Polygonum amphibium*), western dock (*Rumex occidentalis*).

5. *Bog-heath stage.*—In this stage the sedges and grasses of the preceding stage have disappeared, their place being occupied by one to several species of bog-heaths growing on a substratum of *sphagnum.* Sphagnum may invade the *Carex* zone considerably in advance of the bog-heaths or the latter may appear very shortly following sphagnum.

The disappearance of the species of the bog-meadow stage is usually attributed to an increase in the acidity of the water owing to the presence of sphagnum, but from repeated observations in numerous swamps it seems that there is not sufficient increase in acidity to account for this. It is not possible at this time to state definitely the cause of the replacement of the bog-meadow plants by the bog-heaths.

The following are the typical dominants of this stage: leatherleaf (*Chamaedaphne calyculata*), bog rosemary (*Andromeda glaucophylla*), Labrador tea (*Ledum groenlandicum*). Either leatherleaf or bog rosemary may be the first successor of the pioneer sphagnum or both may appear at essentially the same time. In the fully developed stage Labrador tea usually appears as one of the dominants but in some instances does not appear at all. When it does appear it is at a later stage than the other two. Swamp laurel (*Kalmia glauca*) is sometimes present, but usually not in great quantity. It is more abundant northward and occurs rarely in other places.

Along with leatherleaf and bog rosemary on the hummocks of *sphagnum*, is usually to be found a more or less extensive development of small and large cranberry (*Oxycoccus oxycoccus* and *O. macrocarpus*). The bog-heath stage is further marked by the presence of very characteristic herbs among which are pitcher-plant (*Sarracenia purpurea*), sundew (*Drosera rotundifolia*) and three-leaved Solomon's-seal (*Smilacina trifolia*), swamp saxifrage (*Saxifraga pennsylvanica*), cotton-grass (*Eriophorum angustifolium*) and slender cotton-grass are sometimes found. Buck-bean (*Menyanthes trifoliata*), marsh cinquefoil (*Comarum*), and others of the preceding bog-meadow stage may occur also.

6. *Tamarack-spruce stage.*—The formation of sphagnum mounds furnishes suitable conditions for the invasion of tamarack and spruce which soon become established and finally make such a dense growth that the bog-heaths disappear completely.

Tamarack (*Larix laricina*) and black spruce (*Picea mariana*) are the dominants of this stage. Tamarack is the first invader of the bog-heath zone, and in some cases is the sole representative, except for a more or less indefinite zone of spruce along the border of the swamp. Tamarack ranges farther to the south than spruce so that the latter is less abundant as the southern limit of the range is approached. Usually tamarack and spruce are intermingled, or sometimes spruce becomes more abundant and replaces tamarack more or less completely.

When tamarack is the most abundant species the growth is less dense and the lesser reduction of the light intensity may enable the bog-heaths to persist as long as tamarack remains dominant. Leatherleaf and bog rosemary disappear first as they are unable to endure shading, but Labrador tea may persist as long as the swamp itself remains.

A. TYPICAL POND-LILY AND AMPHIBIOUS SEDGE ZONES AROUND BORDERS OF SMALL LAKE WHICH HAS ALREADY BEEN ALMOST FILLED WITH PEAT. ITASCA COUNTY

B. REMARKABLE DEVELOPMENT OF POND-LILIES, COMPLETELY COVERING SURFACE OF WATER IN A LAKE SURROUNDED BY A SUCCESSION OF ZONES OF (1) SEDGES, (2) HEATH SHRUBS, (3) SPRUCE AND TAMARACK, (4) HARDWOOD TIMBER

When the bog becomes filled up with partly decayed sphagnum and rotted wood, or filled around the edges by the washing-in of soil from the sides, arbor-vitae and spruce may replace tamarack completely. When they become more numerous than the tamarack the bog-heaths disappear and the succession advances to the next stage.

If very extensive areas are occupied by a tamarack-spruce swamp it may persist indefinitely as a sub-climax owing to the slowness with which changes take place that will make possible the invasion and establishment of species of the following stage. The natural development may be retarded by burning or lumbering or may be accelerated by draining.

In addition to bog rosemary, leatherleaf and Labrador tea, which belong typically to the preceding stage but persist into this, the following are characteristic shrubs of the tamarack-spruce stage: swamp black currant (*Ribes hudsonianum*), swamp red currant (*Ribes triste*), buckthorn (*Rhamnus alnifolia*), swamp honeysuckle (*Lonicera oblongifolia*).

Many of the herbs which occur in the bog-heath stage are still to be found in this stage. Others are characteristic of this stage since in a regular sequence they appear here for the first time and find their best development here. The following herbs occur on hummocks of living sphagnum: naked miterwort (*Mitella nuda*), small cranberry (*Oxycoccus oxycoccus*), pitcher-plant (*Sarracenia purpurea*), swamp saxifrage (*Saxifraga pennsylvanica*), three-leaved Solomon's-seal (*Smilacina trifolia*), sweet white violet (*Viola blanda*), sundew (*Drosera rotundifolia*), slender cotton-grass (*Eriophorum gracile*).

With the exception of naked miterwort and sweet white violet the plants of the above list are relics of the preceding stage. With these species may also be found: soft sedge (*Carex gynocrates*), bristle-stalked sedge (*Carex leptalea*), glaucous sedge (*Carex paupercula pallens*), scirpus-like sedge (*Carex scirpoides*), soft-leaved sedge (*Carex tenella*), three-fruited sedge (*Carex trisperma*), gold thread (*Coptis trifolia*), white bog orchis (*Habenaria dilatata*), green orchis (*Habenaria hyperborea*), northern bog orchis (*Habenaria obtusata*).

Where sphagnum has died out leaving mounds of humus, and along the border of the swamp where filling up has resulted in the death of sphagnum, the following plants are characteristic: soft-leaved sedge (*Carex tenella*), three-fruited sedge (*Carex trisperma*), snowberry (*Chiogenes hispidula*), yellow clintonia (*Clintonia borealis*), gold thread (*Coptis trifolia*), dwarf dogwood (*Cornus canadensis*), showy lady's-slipper (*Cypripedium hirsutum*), yellow lady's-slipper (*Cypripedium parviflorum*), shield fern (*Dryopteris cristata*), twin flower (*Linnaea borealis*), false lily-of-the-valley (*Unifolium canadense*), interrupted fern (*Osmunda claytoniana*), cinnamon fern (*Osmunda cinnamomeum*), sweet coltsfoot

(*Petasites palmata*), liver-leaf wintergreen (*Pyrola asarifolia*), one-sided wintergreen (*Pyrola secunda*), starflower (*Trientalis americana*).

Snowberry and twinflower are often found on decayed fallen logs where they usually form a dense mat over the surface. Many of the plants of the above list are to be found typically on swamp borders.

7. *Balsam-birch stage.*—The filling-up of a swamp by the washing-in of soil from the sides and in part also by the accumulation and subsequent decay of sphagnum and other plant remains results in the formation of a soil rich in humus, but one in which the water content is much reduced as compared with that of the substratum of the tamarack-spruce or bog-heath stage. The formation of humus and the reduction of water content favors the invasion and establishment of the plants of this stage which marks the passing of the swamp stage and is the predecessor of the pine forest. Drainage of a swamp would accelerate the appearance of the subsequent stages.

The following are the usual dominants: balsam fir (*Abies balsamea*), white spruce (*Picea canadensis*), paper birch (*Betula papyrifera*), yellow birch (*Betula lutea*), arbor-vitae (*Thuja occidentalis*).

All these are not found together in any given area or zone but in the stage of development from spruce-tamarack swamps to the finally dominant pines, combinations of any two or more of these may occur.

8. *The pine association.*—The further filling of a swamp by the carrying in of soil from the sides and by the accumulation of partly decayed plant remains brings about a reduction in the water content of the soil. The reduction of water content and the ability of pine seedlings to grow in a reduced light make it possible for pines to invade and become established. The actual invasion of the balsam-birch zone must occur in the spaces between more widely separated individuals of that zone. The greater longevity of pines as compared with balsam fir, birch, and spruce enables the pines to become dominant in competition with them. The dominant species of pine are: white pine (*Pinus strobus*) and Norway pine (*P. resinosa*). The two species often occur in a mixture, or extensive tracts may be occupied by either as a pure dominant.

IN THE DECIDUOUS FOREST CLIMAX

Swamps having their origin by the filling of lakes in the deciduous forest region go through a series of developmental stages as indicated for the pine forest climax with few variations. In some instances the tamarack-spruce stage is preceded by the bog-heath stage while in other instances the latter does not appear. The principal difference is to be found after the swamp has filled so that the swamp plants are replaced by those of the climax.

A. ZONE OF CATTAILS FRINGING A LAKE IN SOUTHERN MINNESOTA. KING LAKE, NEAR FAIRMONT, MARTIN COUNTY

B. VEGETATIONAL ZONES: (A) BULRUSHES (NEXT TO OPEN WATER); (B) WILLOWS; (C) CATTAILS; (D) WILLOWS (NEXT TO SHORE). PIERCE LAKE, NEAR FAIRMONT, MARTIN COUNTY

In the first three stages of development the dominants and secondary species are the same as indicated under corresponding stages in the development of the pine forest climax and need not be repeated.

4. *The bog-meadow stage.*—The following are the typical dominants of this stage: water sedge (*Carex aquatilis*), bog sedge (*Carex diandra*), slender sedge (*Carex filiformis*), woolly sedge (*Carex lanuginosa*), hairy-fruited sedge (*Carex trichocarpa*), tall manna-grass (*Panicularia americana*), nerved manna-grass (*Panicularia nervata*).

Carex aquatilis and *C. trichocarpa* are less prominent than in the corresponding stages of hydrarch succession culminating in the climax pine forest, their places being taken usually by *Carex filiformis*, *C. lanuginosa*, and *C. diandra*. In many places the former are represented by only a narrow zone while the latter three cover extensive areas. *Panicularia nervata* often occurs abundantly, especially with *C. diandra*. *P. americana* in some places becomes almost a sole dominant in patches or zones in shallow water. The following grasses and sedges are often present: Bebb's sedge (*Carex bebbii*), cyperus-like sedge (*Carex pseudo-cyperus*), retrorse sedge (*Carex retrorsa*), northern manna-grass (*Panicularia borealis*), reed canary-grass (*Phalaris arundinacea*).

5. *Tamarack-spruce stage.*—There are only two dominants in this stage, tamarack (*Larix laricina*) and spruce (*Picea mariana*). Tamarack ranges much farther southward than spruce so that the former is often the only representative of this stage. The following shrubs usually occur in this stage: Bebb's willow (*Salix bebbii*), slender willow (*Salix petiolaris*), hoary willow (*Salix candida*), red-osier dogwood (*Cornus stolonifera*), glaucous willow (*Salix discolor*), swamp birch (*Betula pumila*).

Swamp birch and hoary willow are often the first to invade the bog-meadow stage and sometimes form a scattering zone between it and the tamarack zone. The herbs of this stage are those of the preceding bog-meadow stage which persist into this.

6. *Poplar-birch stage.*—This stage develops when the swamp becomes filled up by the washing-in of eroded materials along the edge and by the accumulation of organic matter from the decay of plant bodies so that the water content is reduced. The reduction in water content enables poplars (*Populus tremuloides*, *P. grandidentata*, and *P. balsamifera*), and birch (*Betula papyrifera*) to invade and become established as the tamaracks die out or as windfalls occur.

7. *Maple-basswood association.*—This represents the final or climax stage and appears as a result of further reduction in the water content of the soil. The invasion of the poplar-birch stage by the species of the climax forest occurs when the poplars or birches die out as the result of competition or when windfalls occur. The fact that maple, basswood,

and others of this stage are longer lived than poplar or birch enables them to crowd out the latter in competition. This stage is represented by the following species: sugar maple (*Acer saccharum*), green ash (*Fraxinus lanceolata*), basswood (*Tilia americana*), bur oak (*Quercus macrocarpa*), white elm (*Ulmus americana*), red oak (*Quercus rubra*). These are usually well mixed and the exclusive dominance of any one of them is rather exceptional although within small areas maple, basswood, or oak may be present in far greater numbers than any of the others. In very sandy soil and farther northward maple disappears and species of oak become more abundant.

IN THE PRAIRIE REGION

In the prairie region the swamp stage is not replaced by trees of either the coniferous or deciduous type. Since it is a region of less rainfall, grass is the highest type of vegetation that is able to develop. Swamps in this region are grass swamps, the bog-heaths and tamarack or spruce are never found. The stages leading up to the swamp are essentially the same as described for the deciduous forest climax. The dominant and secondary species are also identical with those of swamps in the deciduous forest region. As the swamps in the prairie region fill up and become drier the sedges and reed-grasses are replaced by species of manna-grass (*Panicularia*), fowl meadow-grass (*Poa triflora*), timothy (*Agrostis alba*), and finally by bluestem (*Andropogon furcatus* and *A. scoparius*), Indian grass (*Sorghastrum avenaceum*) and porcupine grass (*Stipa spartea*), the typical dominant prairie species, as the habitat becomes drier as the result of further filling.

SWAMPS ORIGINATING BY SECONDARY SUCCESSION

Any cause that destroys the existing vegetation of an area may initiate a secondary succession. Such causes may be changes in the physiography of a region, climatic changes, or changes resulting from the action of biotic agents.

Secondary successions may begin at any point after the pioneer stage and before the final climax. The point at which the succession does begin is determined by the extent to which the water content is affected by the disturbance of the habitat. A secondary succession may be a very local one, such as might be produced by a windfall or by the formation of a small pond, or it may cover an area of hundreds of square miles. In a large area the water content of the habitat is apt to be affected more profoundly, which would cause the secondary succession to begin at an earlier or lower stage. Secondary successions may be classified as (1) flooded succession, and (2) burn or clearing succession. Of the two causes only the former can result in the formation of a swamp. The latter brings about a disturbance of conditions which usually throws the succession back to some earlier stage. Secondary successions due to flooding are essentially the same in all three climax areas so that the following discussion will apply to all.

1. *The flood succession.*—As indicated by the name, this is a succession due to the flooding of an area by any cause. The two principal agents in northern Minnesota are man and beaver. The flooding might be over a very restricted area or over an extensive one, in either case causing a more or less complete hydrarch succession. If over an extensive area, the depth of the water is apt to become sufficient to initiate a primary succession beginning with *Chara* and other plants of that associes.

Beavers by building dams across streams cause a flooding of areas along the streams for some distance above the dams. The areas affected by beaver dams, however, are usually small, although such areas are common.

The topography of a region determines in a large measure the extent to which an area may be affected by flooding and consequently determines the stages at which secondary succession will begin. If the shores of a lake or banks of a stream are high and steep, a rise of several feet in the water-level may produce no very evident effect. On the other hand, if a lake or river is bordered by marsh or swamp, a rise of a foot or even of a few inches may affect the vegetation to a very marked extent.

The first stage of a secondary succession is the pondweed–water-lily stage. Usually the flooding results in the initiation of a succession beginning with the rush–wild rice stage. Cattails are generally the most abundant of the usual dominants, if the flooding be shallow, with bulrushes and reeds where the water is deeper. Of the secondary species, bur-reed, arrow-leaf, and sweet flag are usually developed most extensively. In many cases flooding of a swamp results in the establishment of the bog-meadow stage in all its characteristic features. At whatever stage the succession may begin, the development up to the swamp sub-climax is the same as discussed under origin by primary succession.

In the prairie region, since the bog-meadow stage is the highest development as a swamp, flooding can result only in the initiation of a succession beginning with one of the three stages which normally precede it.

2. *Secondary succession in burned or cleared swamps.*—Burning or clearing in a tamarack-spruce swamp removes the existing vegetation and may also change the conditions of the habitat. Whether it returns at once to the original stage or is replaced by a lower one depends upon the extent to which the habitat is disturbed.

Fire as the more destructive agent affects the habitat more profoundly and causes succession to begin at a lower stage. This is especially true if burning occurs during a dry season when the sphagnum surface is partly dry. At such times burning may result in killing out the sphagnum and in the initiation of a secondary succession beginning with *Carex calamagrostis*. In some instances *Populus* may invade directly after a fire so that a dense growth of seedling poplars is the dominant vegetation.

Thus in the southern half of Minnesota, with the advent of settlers the swamps were cleared of tamarack and then burned, the burning being repeated from year to year, which soon resulted in hay meadows. Such areas are still in the meadow stage but if not disturbed would advance to the deciduous forest which is the climax for that region. In the northern part of the state the same thing is now taking place, the swamps are being cleared of tamarack, spruce, and cedar and then burned which initiates the bog-meadow stage of succession. If undisturbed, swamps in that region would advance to the regional climax of pines.

When a tamarack swamp is drained and afterward burned, the succession begins usually with the bog-meadow stage. As a result of the combined draining and burning, all the characteristic species of the swamp disappear. If the area affected be mowed or burned over each year, it may be kept indefinitely in this stage and valuable hay meadows result.

The removal of the dominant tamarack-spruce layer without subsequent burning does not seriously affect the successional sequence since the water relations of the habitat remain essentially unchanged. The most marked effects are in the changed light relations and increased exposure to evaporation. These changes may result in the disappearance of some of the shade-loving plants.

In extensive swamp areas where filling from the edge can not alter the general conditions of the swamp, the effect of clearing is to permit the development of the bog-shrubs which had been suppressed by tamarack and spruce and consequently in the reëstablishment of an associes of Labrador tea, bog rosemary and leatherleaf. Usually the clearing is not complete, a greater or lesser number of young tamarack and spruce being left. These now develop and with the appearance of new individuals the original tamarack-spruce stage soon becomes dominant again.

In small swamps and in a zone along the edge of larger swamps where the soil is built up more as the result of filling in, an associes of hoary alder, osier dogwood, and species of willow appear after the removal of tamarack and spruce. Swamp birch, swamp honeysuckle, swamp black currant, and swamp red currant occur more or less abundantly with these.

In swamps that are more nearly filled up and where in consequence sphagnum makes little or no growth, spruce, arbor-vitae, balsam fir, birch, and poplars appear in places left vacant by windfalls. In the deciduous forest region the invaders are birch, poplars, and sometimes elm. Osier dogwood, glaucous willow, and, farther northward, hoary alder come in also, but these are later replaced by the trees mentioned above. As the swamp fills up, a balsam fir–birch stage, in the pine region, or birch-poplar stage in the deciduous forest region, becomes established to be succeeded finally by the climax forest of the region as filling is carried on still further.

A tamarack or tamarack-spruce swamp if drained and not disturbed by clearing or burning gradually fills up, thereby reducing the water content of the soil. With the draining away of the water and filling up by washing in of soil around the edges, sphagnum disappears. As the filling proceeds, tamarack dies out, poplars, birch, elm, and occasionally individuals of balsam fir and black ash taking their place. In the pine forest region spruce, balsam fir, and birch are the usual dominants following tamarack as the swamp becomes filled up. The invasion proceeds from the edge where filling occurs most rapidly. As a result of drainage not complicated by other factors, the normal primary succession from tamarack-spruce to the climax forest of the region occurs. Thus it appears that drainage alone merely accelerates the normal primary succession.

POSSIBLE GEOLOGIC CHANGES INDICATED BY CHANGES IN THE STRUCTURE OF PEAT

In some localities along the east coast of North America, evidences of geologic changes, such as the rising or sinking of the land along the coast, are found in a study of the peat bogs, but in Minnesota, no reliable data were found relative to geologic changes of level in the relations of the peat bogs. This is because of the comparatively recent origin of the peat deposits, which are all post-glacial, and because of the frequent disturbances which they have undergone due to other influences, principally fires.

CLIMATIC CHANGES INDICATED BY PLANT SEQUENCES IN PEAT

The general evidence in the peat deposits of the state, tending to show that the climate is now milder than at the beginning of peat accumulation, consists in the gradual transition from plants of the tundra type in lower portions of many of the deposits, to associations of mosses, sedges, shrubs, and trees in the upper portions. Aside from this, there is further evidence of minor climatic changes in the occurrence of several layers of logs and roots separated by intervening layers of moss. While this structure may have been produced by forest fires killing different generations of trees at different times, it seems more probable that the condition is to be explained by oscillations of the water table due to variations of atmospheric humidity or of temperature.

PHYSICAL AND CHEMICAL PROPERTIES OF MINNESOTA PEATS

COLOR AND TEXTURE

The color of the peat in the Minnesota bogs ranges from black to yellowish green, but by far the greatest part of it is dark brown. Next to dark brown, a light brown, or yellowish brown color is most common. All of the peat, regardless of the color when first dug, changes to a slightly darker shade within a few minutes after it is exposed to the air. As it dries, it gradually becomes lighter in shade until finally, when completely dried, the color is decidedly lighter than that of the freshly exposed material.

The sphagnum peat in the big muskeg swamps of northern Minnesota is practically all of the same dark brown color. In the deeper portions of the bogs, where pond peat, or peat which has accumulated under water, is encountered, it is of a much lighter shade and frequently has the greenish color which is typical of peat formed from aquatic plants.

The typical sedge-grass peat is yellowish brown, but this also often appears greenish in the lower levels of the deep bogs.

Black peat has been found only in the bottom portions of the Minnesota bogs. It is usually structureless, and contains considerable soil or mineral matter. It represents the first layers of plant remains which accumulated, and which became mixed with the mud or soil on the original surface of the marsh, or on the bed of the lake in which the peat formed. Muck or very peaty soil, is black, but this material is not true peat, and occurs only in shallow "sloughs" or meadows, and along some stream valleys.

In texture, the Minnesota peats also vary greatly. The texture is dependent upon (1) the type of plants composing the peat, (2) the manner in which the deposit was formed, and (3) the state of decomposition. Most of the peat in Minnesota is fibrous or mossy. This is especially true of the sphagnum peat of the north, but the sedge-grass peat of the south is also fibrous except in the lower parts of the deeper bogs. The bottom portions of the deep filled-lake bogs usually consist of well decomposed material, in which the fibrous texture, if it ever were present, has been destroyed by disintegration. The upper 3 or 4 feet of the sphagnum bogs often consist of a dense mat of moss which shows scarcely any decomposition.

CHEMICAL COMPOSITION

Inspection of analyses shown in the appended table discloses the following facts. The peat containing the least ash was that in the sample from Koochiching County, Locality 202, analysis 128. This sample, which is a composite of four samples collected at intervals of one fourth of a mile along a line across the bog, contains only 4.15 per cent ash. Many composite samples collected in the bogs of the northern part of the state contained less than 10 per cent of ash, while the average ash content of the peat of all the big muskegs of the northern counties is well under 15 per cent, the limit for good fuel.

The peat in central and southern Minnesota contains much more ash than that of the north, and consequently most of these southern bogs are unsuited to the manufacture of peat fuel.

The amount of fixed carbon in the peat of the big deposits in the northern part of the state is, on the average, about 20 per cent. The southern bogs contain a much smaller proportion of fixed carbon.

One of the most noteworthy features of the peat of the state is its unusually high nitrogen content, which will average about 2.25 per cent. The proportions of nitrogen actually found in the 246 samples analyzed varied from .93 per cent at Locality 126a in Koochiching County (analysis 116), to 3.66 per cent at Locality 246 in Hennepin County (analysis 92). Only a few of the samples show a nitrogen content of less than 1.5 per cent.

The sulphur content of the Minnesota peats is more constant than that of any of the other constituents. The proportions of sulphur shown by analyses varies from .13 per cent at Locality 165 in Crow Wing County (analysis 79), to 2.55 per cent at Locality 135 in Marshall County (analysis 140). The amount of sulphur in the great majority of samples is very low. Out of the 246 samples analyzed, only 12 contained sulphur in excess of .99 per cent.

No average analysis of Minnesota peats has been computed for the reason that the figures would be entirely misleading. A few samples of muck from southern Minnesota, with abnormally high ash content, would raise the average ash content to such a point as to convey an entirely erroneous impression as to the quality of the greater part of the peat of the state.

The following table gives the result of the analyses of the 246 samples of peat collected from all parts of Minnesota. The samples were all collected wet, and allowed to dry in the air, and shipped in canvas bags. Consequently the samples as received at the laboratory, contained varying amounts of moisture. All the analyses have been reduced to a moisture free basis.

Analyses of Peat Samples from Minnesota (Analyzed by U. S. Bureau of Mines)

Locality—County	Analysis number	Locality number	Moisture as received	PROXIMATE			ULTIMATE					THERMAL VALUE B.T.U.	
				Volatile matter	Fixed carbon	Ash	Sulphur	Nitrogen	Hydrogen	Carbon	Oxygen	Moisture free	Moisture and ash free
Aitkin	1	17	10.85	54.44	19.05	26.51	.31	2.61	....	....	....	8,134	10,165
"	2	54	....	....	....	....	....	....	....	....	....	....	....
"	3	153	7.75	69.70	23.36	6.94	.20	2.01	....	....	....	9,537	10,248
"	4	152	7.85	69.34	21.87	8.79	.27	2.20	....	....	....	9,156	10,038
"	5	154	7.30	67.85	20.98	11.17	.18	2.16	....	....	....	9,435	10,621
"	6	155	6.60	50.80	14.03	35.17	....	2.01	....	....	....	....	....
"	7	156	7.95	67.30	18.09	14.61	.18	2.23	....	....	....	8,518	9,975
"	8	157	8.15	69.79	21.17	9.04	.16	1.69	....	....	....	8,610	9,466
"	9	158	7.30	68.93	23.73	7.34	.20	1.81	....	....	....	9,469	10,219
"	10	159	....	....	....	....	....	....	....	....	....	....	....
"	11	160	7.50	67.62	21.19	11.19	.18	1.92	....	....	....	8,517	9,590
"	12	161	....	....	....	....	....	....	....	....	....	....	....
"	13	162	7.95	60.95	18.79	20.26	.25	2.46	....	....	....	8,500	10,713
"	14	163	8.90	67.62	23.10	9.28	.23	2.06	....	....	....	8,912	9,824
"	15	164	10.40	68.53	21.15	10.32	.28	2.21	....	....	....	9,090	10,136
"	16	226	7.85	72.00	19.48	8.52	.21	2.26	....	....	....	9,593	10,487
Anoka	17	142	8.35	72.94	14.89	12.17	.27	2.87	....	....	....	8,583	9,772
"	18	143	9.40	62.86	20.53	16.61	.30	2.96	....	....	....	8,062	9,668
"	19	144	8.70	59.09	15.77	25.14	.30	2.88	....	....	....	7,456	9,960
"	20	145	9.00	61.43	17.75	20.82	.27	2.78	....	....	....	7,976	10,073
Becker	21	141	10.45	62.54	15.80	21.66	.95	2.27	....	....	....	9,741	12,434
Beltrami	22	15	11.18	60.63	23.33	16.04	.41	1.73	....	....	....	8,084	9,628
"	23	197	11.25	63.15	20.46	16.39	.33	1.51	....	....	....	7,554	9,035
"	24	16	11.60	53.77	18.37	27.86	.24	1.54	....	....	....	6,406	8,880
"	25	194	11.50	64.97	22.88	12.15	.68	2.82	....	....	....	8,429	9,595
"	26	195	12.10	63.14	19.85	17.01	.53	1.97	4.56	46.19	29.74	7,610	....
"	27	196	12.05	72.71	17.00	10.29	.25	1.31	....	....	....	7,591	8,462
"	28	103	8.95	71.99	12.63	15.38	1.24	2.49	....	....	....	10,906	12,888
"	29	104	8.25	61.12	18.23	20.65	.52	2.21	....	....	....	7,716	9,724
"	30	105	7.80	59.82	13.93	26.25	.84	1.98	....	....	....	7,072	9,589
"	31	106	6.15	43.95	10.34	45.71	....	1.60	....	....	....	....	....
"	32	107	7.90	59.59	18.86	21.55	1.01	2.31	....	....	....	7,703	9,819
"	33	108	7.60	51.01	15.44	33.55	....	1.84	....	....	....	....	....
"	34	109	8.80	62.06	15.08	22.86	.99	1.98	....	....	....	7,515	9,742
"	35	110	10.80	66.65	24.27	9.08	1.54	2.74	....	....	....	9,064	9,969
"	36	123	....	....	....	....	....	....	....	....	....	....	....
"	37	124	....	....	....	....	....	....	....	....	....	....	....
"	38	175	11.60	63.24	23.13	13.63	.33	1.70	....	....	....	7,752	8,975
"	39	176	8.75	64.88	16.33	18.79	1.58	2.88	....	....	....	8,322	10,248
"	40	177	11.10	59.84	20.25	19.91	.42	1.77	....	....	....	7,487	9,348
"	41	134	9.70	70.99	19.85	8.86	.61	2.30	....	....	....	8,765	9,617
"	42	137	11.15	67.75	21.95	10.30	.79	3.04	4.98	50.89	30.02	8,617	....
"	43	138	11.30	65.67	23.23	11.10	.83	3.13	....	....	....	8,591	9,664
"	44	139	10.80	74.10	17.94	7.96	.43	2.95	....	....	....	8,688	9,439

Beltrami—*Continued*	45	189	9.65	70.50	17.71	11.79	.23	2.86				8,550	9,693
"	46	190	9.80	70.84	18.46	10.70	.24	2.53				8,583	10,823
Blue Earth	47	99	8.60	49.87	6.64	43.49		2.22					
"	48	100	8.90	58.95	16.74	24.31	.35	2.83				7,450	9,843
"	49	101	9.20	57.10	17.73	25.17	.33	2.86				7,239	9,674
"	50	56	6.98	43.00	8.62	48.38	.45	2.40				4,593	8,897
"	51	57	8.05	49.95	17.88	32.17	.46	2.53				6,525	9,620
"	52	59	8.23	61.75	20.51	17.74	.29	2.53				7,791	9,471
"	53	60	8.63	53.90	18.98	27.12	.26	2.35				6,904	9,473
"	54	61	8.48	49.20	16.51	34.29	.36	2.53				6,203	9,440
"	55	62	8.88	54.73	17.47	27.80	.40	2.81				6,736	9,330
"	56	63	9.53	59.88	21.57	18.55	.33	2.80				7,696	9,449
"	57	64	9.40	53.51	20.17	26.32	.39	2.72				6,983	9,478
"	58	66	9.58	56.18	19.46	24.36	.41	3.01				7,172	9,482
"	59	67	9.63	63.41	20.79	15.80	.27	2.92				8,023	9,528
"	60	70	6.83	47.12	15.34	37.54	.76	2.35				5,972	9,561
"	61	79	6.53	50.66	14.84	34.50	.45	2.75				6,273	9,576
"	62	80	7.93	59.90	19.49	20.61	.34	3.10				7,555	9,516
"	63	81	8.45	61.33	18.68	19.99	.33	3.13				7,566	9,457
"	64	82	7.65	60.18	19.03	20.79	.45	3.00				7,517	9,490
Carlton	65	13	11.35	65.82	23.54	10.64	.26	1.84	4.27	51.63	31.36	8,839	9,892
"	66	214	7.75	55.66	13.17	31.17	.31	2.76				6,885	10,002
"	67	215	7.60	68.31	23.50	8.19	.19	1.82				9,124	9,938
"	68	216	7.85	67.12	21.54	11.34	.21	2.04				8,932	10,075
Cass	69	125	11.20	63.91	22.75	13.43	.46	1.95				8,492	9,799
"	70	149											
"	71	150	8.10	49.51	15.67	34.82		2.07					
"	72	151	8.45	69.58	20.81	9.61	.19	1.75				8,427	9,323
"	73	166	10.70	66.01	18.59	15.40	.21	2.39				7,923	9,365
"	74	167	9.45	73.72	18.55	7.73	.21	2.15				9,042	9,800
Cottonwood	75	111	7.10	41.60	3.34	55.06		1.92					
Crow Wing	76	42	10.15	64.75	24.45	10.80	.28	2.84				8,553	9,589
"	77	43	9.78	65.51	24.20	10.29	.43	3.03				8,894	9,914
"	78	55	8.75			16.5							
"	79	165	7.80	61.23	17.51	21.26	.13	2.65				7,456	9,350
Dakota	80	253	9.00	68.02	19.40	12.58	1.34	2.40				8,346	9,547
Douglas	81	130	9.10	59.74	11.71	28.55		2.26					
"	82	131	10.80	64.07	18.78	17.15	.48	2.76				7,994	9,649
"	83	132	10.05	57.14	17.57	25.29	.32	2.67				7,173	9,601
"	84	133	11.15	66.63	16.94	16.43	.28	2.87				8,150	9,752
Faribault	85	102	7.40	46.14	4.08	49.78		2.27					
Freeborn	86	94	7.05	41.90	9.90	48.20	.15	1.94	3.18	29.56	16.97		
"	87	94a	7.55	41.81	9.62	48.57		1.95					
"	88	94b	5.55	26.20	4.93	68.87		1.22					
"	89	95	8.45	42.85	8.16	48.99		2.33					
"	90	96	6.50	34.22	5.94	59.84		1.60					
"	91	97	9.25	52.29	13.94	33.77		2.75					
Hennepin	92	246	8.55	62.00	17.66	20.34	.61	3.66				8,014	10,060
"	93	247	8.60	71.01	17.67	11.32	.30	2.49				8,151	9,191
"	94	248	9.05	67.89	15.29	16.82	.21	2.80				7,655	9,203
"	95	249	10.10	72.02	15.97	12.01	.46	3.43				8,210	9,331
"	96	250	9.50	67.73	19.95	12.32	.61	3.29				8,523	9,720
"	97	252	9.10	72.66	15.79	11.55	.36	2.95				8,497	9,607

Analyses of Peat Samples from Minnesota (Analyzed by U. S. Bureau of Mines)—Continued

Locality—County	Analysis number	Locality number	Moisture as received	PROXIMATE			ULTIMATE					THERMAL VALUE B.T.U.	
				Volatile matter	Fixed carbon	Ash	Sulphur	Nitrogen	Hydrogen	Carbon	Oxygen	Moisture free	Moisture and ash free
Hubbard........	98	112	12.70	61.09	17.55	21.36	1.19	2.04	....	....	....	7,267	9,241
"	99	113	9.30	63.89	21.45	14.66	.56	2.22	....	....	....	8,286	9,709
"	100	113a	10.40	66.77	23.35	9.88	.37	2.05	....	....	....	8,526	9,461
Isanti........	101	244	8.40	68.78	20.74	10.48	.28	2.49	....	....	....	8,960	10,008
"	102	245	7.70	73.29	20.43	6.28	.25	2.71	....	....	....	9,538	10,178
Itasca........	103	114	8.35	60.17	19.92	19.91	.23	1.96	....	....	....	7,835	9,783
"	104	115	8.05	66.94	20.01	13.05	.24	2.12	....	....	....	8,884	10,217
"	105	118	9.60	71.68	21.57	6.75	.29	1.75	....	....	....	8,823	9,462
"	106	119	9.35	69.44	20.58	9.98	.23	1.65	....	....	....	8,554	9,502
"	107	119a	9.45	69.30	19.82	10.88	.29	1.81	....	....	....	9,002	10,101
"	108	119b	10.20	69.15	17.54	13.31	.40	2.22	....	....	....	8,700	10,038
"	109	120	11.00	70.96	22.80	6.24	.17	1.04	....	....	....	8,366	8,923
"	110	121	8.40	59.15	19.67	21.18	.21	2.02	....	....	....	7,854	9,964
"	111	122	9.95	67.41	21.04	11.55	.29	2.64	....	....	....	8,732	9,872
"	112	146	8.45	65.97	22.34	11.69	.21	2.05	....	....	....	8,875	10,050
"	113	147	9.95	66.52	22.04	11.44	.26	2.05	....	....	....	8,580	9,688
"	114	148	9.80	65.13	25.61	9.26	.40	1.75	....	....	....	8,588	9,464
Koochiching........	115	126	10.60	58.28	18.45	23.27	.58	1.72	....	....	....	7,308	9,524
"	116	126a	7.80	42.25	11.27	46.48	....	.93	....	....	....	....	....
"	117	168	11.05	66.67	19.45	13.88	1.33	1.94	....	....	....	8,192	9,512
"	118	169	10.15	69.34	21.87	8.79	.75	2.23	....	....	....	8,640	9,473
"	119	170	11.35	68.58	20.14	11.28	.24	1.35	....	....	....	7,753	8,739
"	120	171	10.90	64.81	23.57	11.62	.37	1.72	....	....	....	8,146	9,217
"	121	172	8.60	67.78	20.51	11.71	.21	1.51	....	....	....	8,394	9,507
"	122	173	9.95	68.63	22.21	9.16	.22	1.78	....	....	....	8,406	9,254
"	123	174	12.50	67.31	23.66	9.03	.24	1.86	....	....	....	8,375	9,206
"	124	198	10.65	67.10	23.00	9.90	.41	1.79	....	....	....	8,637	9,586
"	125	199	10.35	67.76	24.77	7.47	.33	1.99	....	....	....	8,868	9,584
"	126	200	9.80	74.72	18.18	7.10	.37	2.08	....	....	....	9,074	9,767
"	127	201	9.70	74.25	20.60	5.15	.19	1.81	....	....	....	9,007	9,496
"	128	202	9.65	74.54	21.31	4.15	.23	2.49	....	....	....	9,211	9,610
"	129	203	10.30	72.46	20.35	7.19	.36	2.12	....	....	....	8,795	9,476
"	130	204	9.85	69.27	22.97	7.76	.70	1.53	....	....	....	8,940	9,693
"	131	205	10.75	68.57	21.57	9.86	.43	1.29	....	....	....	8,314	9,223
"	132	205a	10.25	68.80	22.79	8.41	....	....	....	....	....	8,589	....
"	133	206	9.50	73.37	20.11	6.52	.24	1.44	....	....	....	9,330	9,981
"	134	207	9.15	70.61	23.06	6.33	.35	1.90	....	....	....	9,171	9,791
"	135	208	9.50	81.44	13.48	5.08	.35	1.60	....	....	....	9,408	9,912
"	136	209	9.65	82.62	11.24	6.14	.40	2.60	....	....	....	9,516	10,139
"	137	210	10.15	71.40	22.81	5.79	.79	2.28	....	....	....	9,428	10,007
Lake........	138	211	8.80	73.03	19.40	7.57	.25	1.64	....	....	....	8,815	9,537
"	139	212	9.60	64.33	20.57	15.10	.41	1.92	....	....	....	8,144	9,592

Marshall	140	135	10.60	67.73	18.18	14.09	2.55	2.81	...	...	...	8,153	9,490
"	141	136	9.75	70.19	18.90	10.91	1.52	2.86	...	...	...	8,666	9,727
"	142	178	11.30	68.38	20.40	11.22	.36	3.08	...	...	...	8,452	9,520
"	143	179	10.90	67.45	21.89	10.66	.38	2.53	...	...	...	8,506	9,521
Mille Laos	144	225	8.55	71.90	20.61	7.49	.19	1.45	...	...	...	8,842	9,558
Morrison	145	227	8.20	66.39	20.37	13.24	.27	2.51	...	...	...	8,345	9,619
Olmsted	146	98	8.55	43.55	11.45	45.00	...	1.78	...	...	...	...	...
Ottertail	147	231	11.00	61.24	18.65	20.11	.30	1.72	...	...	...	7,288	9,122
"	148	233	10.10	69.36	16.29	14.35	.21	3.28	...	...	...	8,135	9,498
"	149	234	9.55	67.94	18.63	13.43	.28	2.99	...	...	...	8,199	9,471
"	150	235	8.85	57.38	19.14	23.48	.25	2.61	...	...	...	7,277	9,510
"	151	236	8.85	61.49	18.76	19.75	.30	2.78	...	...	...	7,865	9,801
Pine	152	217	8.10	63.77	20.07	16.16	.21	1.63	...	...	...	8,745	10,431
"	153	218	8.75	68.38	20.61	11.01	.23	1.68	...	...	...	8,971	10,081
"	154	219	7.70	68.85	20.26	10.89	.18	1.93	...	...	...	8,631	9,685
"	155	220	9.25	66.61	18.73	14.66	.25	2.48	...	...	...	8,087	9,476
"	156	221	9.45	70.62	19.05	10.33	.25	2.30	...	...	...	8,738	9,744
"	157	222	8.60	71.39	21.55	7.06	.23	2.22	...	...	...	9,383	10,096
"	158	223	8.00	72.77	19.95	7.28	.21	2.50	...	...	...	9,174	9,894
"	159	224	8.70	71.74	20.43	7.83	.24	2.83	...	...	...	9,025	9,792
Polk	160	140	9.76	53.85	9.86	36.29	...	2.49	...	...	...	...	...
Ramsey	161	83	4.85	31.11	3.73	65.16	...	1.50	...	...	...	...	...
"	162	84	10.35	71.65	16.81	11.54	.21	2.88	...	...	...	8,210	9,281
"	163	85	5.75	49.50	1.53	48.97	...	1.81	...	...	...	...	...
"	164	251	8.95	69.25	14.50	16.25	.44	2.97	...	...	...	7,708	9,203
Rice	165	254	7.50	68.65	18.81	12.54	.29	2.76	...	...	...	8,365	9,565
Roseau	166	127	11.45	65.95	18.86	15.19	.36	2.77	...	...	...	7,915	9,333
"	167	128	11.50	69.66	20.96	9.38	.33	2.63	...	...	...	8,407	9,277
"	168	180	10.85	71.17	20.81	8.02	.99	2.56	...	...	...	8,573	9,321
"	169	181	10.95	71.14	20.33	8.53	.73	3.01	...	...	...	8,837	9,561
"	170	182	11.05	71.22	20.80	7.98	1.29	3.04	...	...	...	8,886	9,657
"	171	183	11.60	71.21	22.23	6.56	.44	2.52	...	...	...	8,855	9,477
"	172	184	10.15	70.28	21.04	8.68	.62	2.68	...	...	...	8,538	9,350
"	173	185	7.65	43.69	11.81	44.50	.31	1.83	...	...	...	5,010	9,027
"	174	186	11.25	69.01	19.33	11.66	.79	2.45	...	...	...	8,247	9,336
"	175	187	11.70	65.46	22.25	12.29	.58	2.70	...	...	...	7,985	9,104
"	176	188	10.00	69.17	22.83	8.00	.37	2.26	...	...	...	8,544	9,287
"	177	191	7.85	37.98	6.89	55.13	.15	1.03	...	...	...	4,042	9,008
"	178	192	10.85	73.02	16.94	10.04	.25	2.16	...	...	...	8,328	9,257
"	179	193	9.90	69.26	18.20	12.54	.64	2.16	5.20	48.32	31.14	8,232	...
St. Louis	180	1	10.18	59.14	20.88	19.98	.33	1.83	...	...	...	8,134	10,165
"	181	2	11.00	51.63	18.31	30.06	1.09	2.01	...	...	...	6,917	9,890
"	182	213	7.60	66.65	21.41	11.94	.20	1.64	...	...	...	8,986	10,204
"	183	5	11.85	50.31	15.79	33.90	.40	1.40	...	...	...	5,995	9,070
"	184	7	11.18	58.51	21.64	19.85	.28	1.88	...	...	...	7,743	9,660
"	185	6	10.55	62.72	23.16	14.12	.30	1.79	...	...	...	8,590	10,003
"	186	8	10.85	64.87	24.19	10.94	.27	1.39	4.90	49.32	33.18	8,363	9,391
"	187	9	11.60	62.25	22.65	15.10	.34	2.51	...	...	...	8,467	9,973
"	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

Analyses of Peat Samples from Minnesota (Analyzed by U. S. Bureau of Mines)—Continued

Locality—County	Analysis number	Locality number	Moisture as received	PROXIMATE			ULTIMATE					THERMAL VALUE B.T.U.	
				Volatile matter	Fixed carbon	Ash	Sulphur	Nitrogen	Hydrogen	Carbon	Oxygen	Moisture free	Moisture and ash free
St. Louis—*Continued*	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	9,711
"	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	9,954
"	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	9,811
"	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
"	217	44	8.55	69.91	24.32	5.77	.23	1.49	....	....	....	9,196	9,759
"	218	45	8.88	69.94	21.88	8.18	.30	2.80	....	....	....	9,059	9,867
"	219	46	8.50	63.42	23.38	13.20	.25	2.17	....	....	....	8,693	10,015
"	220	47	8.45	66.77	21.92	11.31	.26	2.47	....	....	....	9,061	10,216
"	221	48	8.75	69.02	22.76	8.22	.24	2.70	....	....	....	8,985	9,790
"	222	49	9.28	64.32	25.65	10.03	.25	1.85	....	....	....	9,010	10,015
"	223	50	8.80	65.90	26.50	7.60	.27	2.32	....	....	....	9,173	9,928
"	224	51	6.45	50.08	19.40	30.52	.16	1.51	....	....	....	7,458	10,734
"	225	52	9.88	62.36	24.49	13.15	.36	2.42	....	....	....	8,753	10,078
"	226	53	10.10	63.07	24.36	12.57	.32	2.53	....	....	....	8,778	10,040
"	227	116	9.40	70.64	20.14	9.22	.19	1.40	....	....	....	8,285	9,126
"	228	117	10.15	69.65	21.45	8.90	.30	2.09	....	....	....	8,648	9,493
"	229	117a	10.55	66.74	20.96	12.30	.38	1.93	....	....	....	8,381	9,556
Sherburne	230	243	5.80	50.96	10.24	38.80	.23	2.28	....	....	....	6,162	10,069
"	231	14	9.93	51.43	13.82	34.75	1.07	2.33	....	....	....	6,213	9,522
Stearns	232	129	8.95	57.94	16.30	25.76	.45	2.69	....	....	....	7,183	9,675
"	233	242	7.50	54.81	10.92	34.27	.37	3.11	....	....	....	6,381	9,707

Steele	234	86	7.75	46.02	11.22	42.76	....	2.23	....	....	....	....	....
"	235	87	7.55	49.92	9.57	40.51	....	2.90	....	....	....	....	....
"	236	91	8.40	49.13	11.13	39.74	....	2.24	....	....	....	....	....
"	237	92	8.85	53.52	11.81	34.67	....	2.40	....	....	....	....	....
"	238	93	7.05	52.12	4.20	43.68	.33	2.25	3.29	30.01	20.44	....	....
Todd	239	237	8.90	61.92	18.66	19.43	.30	2.78	....	....	....	8,024	9,959
"	240	239	8.55	58.12	19.41	22.47	.24	2.88	....	....	....	7,403	9,548
"	241	240	9.05	57.12	13.25	29.63	.74	2.84	....	....	....	6,412	9,112
"	242	241	9.65	64.42	21.47	14.11	.29	2.91	....	....	....	8,165	9,506
Wadena	243	230	8.80	59.27	13.10	27.63	.21	2.72	....	....	....	6,707	9,268
Waseca	244	88	12.00	61.02	20.23	18.75	.47	2.93	....	....	....	7,887	9,,707
"	245	89	8.75	57.26	14.90	27.84	.28	3.08	4.28	38.67	25.85	6,139	6728
"	246	90	8.45	48.26	14.33	37.41	....	1.73	....	....	....	....	....

COMPARISON WITH PEATS FROM OTHER LOCALITIES

The high quality of Minnesota peats may be better understood by comparing their compositions with those of the following typical peats from other regions.

Table Showing Average, Maximum, and Minimum Values of Proximate Analyses of Wisconsin Peat[55]

	Average	Range Maximum	Range Minimum
Moisture in raw peat, per cent	84.5	93.3	64.1
Moisture in air-dried peat, per cent	26.9	58.5	14.0
Volatile matter, per cent	56.4	71.3	23.7
Fixed carbon, per cent	24.0	32.3	5.9
Ash, per cent	19.5	70.4	5.5
Sulphur, per cent	0.55	1.67	0.16
B. T. U., per pound	8,070	10,600	3,202
Combustible contents, per cent	80.4	....	....
Carbon, per cent	46.3	51.0	40.3
Hydrogen, per cent	4.6	4.9	4.4
Oxygen, per cent	26.4	27.5	25.1
Nitrogen	2.35	2.9	1.7

Charles A. Davis[56] reports the ash contents for 18 samples of Michigan peat to range from 1.3 per cent to 18.8 per cent. Davis also gives the following analyses of Michigan peats:

No.	County	Per cent ash	Per cent fixed carbon	Per cent volatile matter	B. T. U's per lb.	Remarks
1.	Luce	4.4	....	....	10,600	Peat very fibrous in appearance
2.	Luce	....	....	....	10,000	
3.	Luce	4.0	....	....	8,250	Very fine structure
4.	St. Clair	3.5	....	....	9,550	
5.	Jackson	9.0	27.3	63.7	8,000	
6.	Jackson	3.2	28.6	68.2	8,600	
7.	Jackson	8.8	24.0	67.0	8,200	Dense black color
8.	Jackson	5.15	30.0	64.7	9,700	Very light peat
9.	Jackson	5.8	25.0	69.8	10,280	Very light peat
10.	Jackson	7.6	31.0	61.3	8,400	
11.	Jackson	10.3	29.4	60.5	8,750	
12.	Jackson	10.1	30.8	58.8	9,100	
13.	Washtenaw	7.7	30.9	61.5	8,900	Dark reddish color
14.	Washtenaw	10.1	23.6	66.2	8,200	
15.	Washtenaw	10.2	26.7	63.2	8,600	
16.	Washtenaw	1.8	30.3	68.0	9,500	Fibrous structure
17.	Washtenaw	1.3	29.8	68.5	10,300	Fibrous structure
18.	Washtenaw	2.0	28.0	70.0	10,100	Fibrous structure
19.	Washtenaw	18.8	26.3	55.2	7,550	Celery farm land

Out of 54 samples of Maine peat collected by E. S. Bastin,[57] and Charles A. Davis, 45 showed an ash content of less than 15 per cent; 39 showed less than 10 per cent ash; while 9 contained less than 5 per cent. The volatile combustible matter ranged from 50 per cent to 70 per cent and the fixed carbon from 25 per cent to 35 per cent.

The average composition of 57 samples of peat from Sweden[58] was determined as follows:

[55] F. W. Huels, *op. cit.* p. 162.

[56] Charles A. Davis, The Origin and Distribution of Peat in Michigan. *Rep. Mich. State Bd. Geological Survey* p. 328. 1906.

[57] E. S. Bastin, and C. A. Davis, The Peat Deposits of Maine. *Bulletin* 376. U. S. Geol. Survey. 1909.

[58] *Svenska Mosskulturforeningens Tidskrift.* January, 1905.

Air-Dried Peat

Moisture	27.17 per cent
Ash	3.27 per cent
Combustible substance	69.56 per cent

The following table, taken from *Mosebladet*, July 1907, shows the composition of some typical peat from Denmark:

Peat Fuel from Denmark

Locality	Ash	Sulphur	Nitrogen	Organic substance	Moisture	Caloric value of sample with its percentage of moisture, Calories
Bjornkaer	4.1	0.31	....	70.69	25.0	3,730
Lyngen	8.0	0.30	....	66.70	25.0	3,600
Korsor	10.8	1.80	1.2	62.40	25.0	3,280
Axelvold	4.4	0.63	1.5	68.50	25.0	3,574
Pindstrup	0.84	trace	0.72	74.10	25.0	3,330
Okaer	8.10	....	....	66.90	25.0	3,343
Sparkaer	5.00	....	....	70.00	25.0	3,644
Herning	1.40	....	....	73.40	25.0	3,582

Average Composition of Irish Peat[59]

Constituents	Perfectly dry	Including 25 per cent moisture	Including 30 per cent moisture
Carbon	59.0	44.0	41.2
Hydrogen	6.0	4.5	4.2
Oxygen	30.0	22.5	21.0
Nitrogen	1.25	1.0	0.8
Ash	4.0	3.0	2.8
Moisture	....	25.0	30.0

Composition of Canadian Peats
Analyzed by Bureau of Mines, Toronto, and by the Geological Survey Department

Peat from	Moisture per cent	Ash per cent	Combustible substance per cent
Welland	25.0	3.58	71.42
Perth	25.0	7.29	67.71
Brockville	25.0	8.20	66.80
Rondeau	25.0	7.03	67.97
Newington	25.0	0.92	74.08
Prince Edward Island	25.0	2.82	72.18
Ste. Therese	8.86	9.50	81.64

FUEL VALUE OF MINNESOTA PEATS

The fuel value of Minnesota peat as shown by the analyses of the 246 samples given in the table with the chemical analyses, pages 76 to 81, inclusive, varies from 4,012 to 10,906 B.T.U. per pound of moisture-free peat. The average is 8,239 B.T.U. per pound. Omitting the impure mucks of southern Minnesota, the average thermal value is over 9,000 B.T.U. per pound. This fuel value compares favorably

[59] Sturtevant. Mechanical Draft p. 42.

with that of peat from other regions both in the United States and Europe.

FUEL VALUE OF PEAT FROM OTHER REGIONS

The average heating value of Wisconsin peat, in B.T.U. per pound of dry peat is given by Huels[60] as 8,070.

The average fuel value of 57 samples of dried peat from Sweden showed 9,478 B.T.U. per pound.

Swedish Scale for Comparing Fuel Value[61]

	Very high	High	Average	Low	Very low
Calories per kilogram	5,600	5,300	5,000	4,700	4,400
British thermal units	10,080	9,540	9,000	8,460	7,920

The analyses of 18 samples of dried peat from Michigan,[62] as given by C. A. Davis, showed fuel values ranging from 7,500 to 10,000 B.T.U. per pound.

The fuel values of 29 samples of Indiana[63] peat ranged from about 7,000 to 10,000 B.T.U.

Out of 54 determinations from samples of Maine[64] peats most of them showed fuel values between 8,100 and 9,800 B.T.U.

Comparative Fuel Value of Air-Dried Peat and Coal[65]

Coal and Coke

Type of fuel	Locality	Heating value B.T.U.
Graphitic anthracite	Cranstone, R. I	10,996
Coke	Mixed coke	12,366
Anthracite	St. Nicholas, Pa	12,523
Anthracite	Blacksburg, Va	11,961
Semianthracite	Spadra, Ark	12,460
Semibituminous (Pocahontas No. 3)	Ennis, W. Va	14,290
Bituminous (Pittsburg)	Connellsville, Pa	13,365
Bituminous (Illinois)	Zeigler, Ill	11,686
Bituminous (Illinois)	LaSalle, Ill	11,399
Bituminous (Wyoming)	Hanna, Wyo	10,706
Lignite (Texas)	Olsen, Texas	7,870
Lignite (North Dakota)	Wilton, N. Dak	7,069

Air-Dried Peat

Sample	Locality	Heating value B. T. U. Water-free
Average	Minnesota	....
Average	Wisconsin	8,070
Average of 18 samples	Michigan	7,500 – 10,000
Average of 29 samples	Indiana	7,000 – 10,000
Average of 54 samples	Maine	8,100 – 9,800
Average of 57 samples	Sweden	9,478

For most purposes of comparison it will be approximately correct to estimate the heating value of average peat to be slightly greater than .6 of the heating value of ordinary bituminous coal. The best peat has

60 F. W. Huels, *op. cit.*

61 Charles A. Davis, *op. cit.*

62 *Ibid.*

63 A. E. Taylor, Thirty-first Ann. Rep. Dept. Geol. and Nat. Resources, Indiana p. 111. 1906.

64 E. S. Bastin, and Charles A. Davis, *op. cit.*

65 Chas. A. Davis, The Uses of Peat, *Bulletin* 16, U. S. Bureau of Mines p. 53. 1911.

A. PUTTING DOWN TEST HOLES IN A PEAT BOG WITH THE DAVIS PEAT SAMPLER. THIS SHOWS THE OPERATION OF FORCING THE RODS DOWN THROUGH THE PEAT

B. DRAWING UP THE PEAT SAMPLE WITH THE DAVIS PEAT SAMPLER. THE SAMPLER HAS JUST BEEN PULLED OUT OF THE HOLE WITH THE CYLINDER FULL OF PEAT

about 75 per cent of the heating value of anthracites, and 80 per cent of the heating value of Illinois coal.

METHODS USED IN PROSPECTING AND TESTING PEAT BOGS

ESTIMATION OF AREA OF THE BOGS

It has not been possible to test many of the bogs, in the time available for the work, in great detail. It is doubtful whether the results of such a detailed survey, were it undertaken, would justify the great expense that would be involved. The peat bogs, in Cook, St. Louis, Koochiching, Beltrami, Clearwater, Aitkin, Crow Wing, Itasca, and portions of adjoining counties, are already mapped with a fair degree of accuracy on the old government township maps. Several counties, including Rice, Blue Earth, Ramsey, Carlton, Polk, Pennington, and Goodhue, have soil maps, surveyed by the Bureau of Soils, U. S. Department of Agriculture, which show the exact boundaries of the peat deposits in those counties, or in their surveyed portions. The maps of the northern counties, compiled from Government township plats, were intended to show "swamp lands" only, but since the swamps of northern Minnesota practically all contain peat, the maps in reality show the peat bogs. These various maps of the northern half of the state, and particularly the map showing the surface formations of northwestern Minnesota, by Professor Frank Leverett,[66] have been used to a large extent in determining the areas of the bogs studied in connection with this report and in figuring estimates of the quantity of peat available in the northern half of the state. In southern Minnesota no maps were available showing swamp or peat lands with the exception of the few counties already mentioned, in which soil surveys had been completed. Estimates of areas in this part of the state had been made on the ground in the course of the field investigations of the bogs.

DETERMINATION OF THE DEPTH AND STRUCTURE OF THE PEAT SAMPLES

The Davis peat sampler, an instrument patented by the late Dr. Charles A. Davis, of the U. S. Bureau of Mines, and especially designed for making soundings and taking samples of peat bogs, was used throughout the work. The essential part of this tool (see Plate XIX) is a stout brass tube about a foot long and seven eighths of an inch in inside diameter. The lower edge of the tube is sharpened, and inside the upper end is closely fitted and riveted a shoulder or ring of brass one sixteenth of an inch thick to serve as a stop for the piston and catch. Inside the cylinder is a brass piston of three-fourths inch rod accurately fitting the opening in the upper part of the tube and bushed out at the lower end by a ring of brass to fit the cylinder. This lower end of the piston

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[66] Frank Leverett, and U. G. Purssell, *op. cit.*

is slotted on one side, and in the slot is fastened a brass spring catch which automatically locks when the piston is drawn up and out of the cylinder. A metal peg driven through a hole in the piston at the proper distance from its upper end and at right angles to its long axis prevents its being pushed out of the cylinder at the outlet end. The whole tool can be quickly and firmly fastened to a rod of gas pipe by a screw thread in the upper end of the piston. When used, this tool is pushed down into the peat the required distance, with the plunger filling the cylinder. A sample is taken by drawing up the rod and the attached piston until the catch is heard to lock at the top of the cylinder, after which the cylinder is pushed down into the peat about its own length. This fills it unless the peat is very wet or very hard. After it is full it may be drawn to the surface without danger of loss or of mixing with the overlying material. The sample thus inclosed may then be pushed from the cylinder by unlocking and pushing in the piston. By using this tool the depth and character of any peat bed may be accurately learned with a relatively small expenditure of time and labor.

DEPTH AND STRUCTURE

The depth of each peat deposit referred to in this report is the vertical distance from the surface to mineral soil. The depth of workable peat is the vertical distance from the surface to the top of beds that are sandy or clayey. The depths were usually obtained by running a line of test holes, made with the peat sampler, along the axis of the bog. In the smaller bogs, lines of holes at right angles to the first line were often run. The intervals between holes in the same bog were taken, approximately the same length where practicable. The distance between holes was varied in different deposits according to the size of the bog and the irregularities which developed in the structure and depth of the peat. In the very large swamps of northern Minnesota, the holes were usually spaced one quarter mile apart, but in some one mile apart.

The Davis peat sampler not only secures a sample from any depth uncontaminated by the overlying material, but also preserves in the sample core the exact structure of the peat. If there is a sudden change in the composition or structure of the material, the sample will show it, and moreover, the exact depth at which this change occurs may be readily determined. For instance in the bogs which represent filled lakes and over which successive layers of sphagnum moss have built up the deposit for 8 or 10 feet above the old level of the surface of the water in the lake, the exact elevation of this former water level may be determined by the sharp change in the composition and structure of the peat, which always occurs at that horizon. At some places, at great depths in the deepest bogs of the filled-lake type, there is such a large amount of water present, and the peat is so fluid, that the sample will not remain in the core barrel of the sampling instrument. A few of the northern bogs exhibited such conditions near the bottom, and consequently no samples could be obtained below the top of the fluid mixture of water and peat. Plate XIX shows the method of testing a bog with the Davis peat sampler.

COLLECTION OF SAMPLES FOR ANALYSIS

In bogs of small or moderate size, the samples taken should be representative of the whole deposit, since they furnish the most accurate basis upon which to calculate the value of the deposit. However, this is impracticable in the immense swamps in northern Minnesota where single peat bogs often contain many square miles, and some, one hundred square miles or more. Consequently the method of sampling had to be adapted to the size and depth of the bogs.

In the smaller bogs, the samples were made up by mixing the material obtained from all the test holes and from various depths in each hole. The samples for analyses can thus be collected while the soundings for depth are being made. The rule adopted was to bring up a sample from every 2 feet in depth from each hole. The entire sample brought up at each test hole was preserved. When the material became too bulky to be contained in one sample sack, a second one was filled and given the same number. These were afterwards mixed and an average sample secured. In a few cases, samples were collected at various depths where a change in the composition of the peat was indicated, instead of every 2 feet. In many peat deposits a change in the composition of the peat becomes evident by a change of color and texture. Thus, fibrous, poorly decomposed, brown peat may be replaced at a certain depth below the surface by greenish, or yellowish, finely divided material, that is entirely different in its appearance and properties from that found above. If the peat was very greenish, or very light colored, or gray, samples were not mixed with the purer peat from above, as this deeper material often contains too much ash to be of commercial value. The sequence of the beds was, however, followed to the bottom of the deposit, in order to gain complete data as to the depth and structure of the deposit.

In the large bogs, covering an area of several square miles or more, separate samples were taken from each mile of test holes. The same method of saving the material from each 2 feet in depth from each hole was followed in the big bogs as in the smaller ones. With test holes spaced every ¼ mile, each sample made up represented a composite, or average, of one mile of the deposit.

The size of the samples taken was kept as uniform as possible. Small canvas sacks were used, which held about 5 pounds of wet peat. This, when dry, weighed less than 1 pound. A mixed sample, which will weigh a few ounces when dry is sufficient for determining the fuel value and chemical composition of the peat.

RECORDING TEST HOLES AND SAMPLES

The test holes put down to secure a sample were numbered consecutively, and each sample was given a locality number. Thus, if the locality number were no. 35 and the material from 4 test holes included, they would be numbered 35–1; 35–2; etc. The depth and character of the peat were described in the note book for each test hole, and a record of the number of test holes made to secure the sample was kept. The locations of the test holes were usually described by township, range, and section, since the majority of the samples were collected along section lines, and most of them at section corners or quarter-corners. Where this method of location could not be followed, a sketch map of the deposit was made, and the locations of the holes platted on the map.

LABELLING SAMPLES

The numbers given the sample (locality number) were marked on the sack in indelible pencil, so that in squeezing the water from the sack the numbers were not obliterated. Before the material was sent to the chemical laboratory, separate labels were made out for each sample and included within the sacks, and duplicate labels, with additional data, were sent by mail, to accompany the samples.

SAMPLES FOR DETERMINATION OF PLANT CONTENTS

Samples were frequently taken also for identification of the plant contents. These were carefully packed in air-tight aluminum soil cans, or, for short periods, in heavy envelopes, and were sent to the laboratory to be examined with the microscope. At least one complete set of such samples was taken from every 1 foot in depth, top to bottom, for each type of peat bog.

WET AND DRY SAMPLES

It has been found that the collection of wet samples in air-tight cans or tubes for fuel and chemical analyses serves no important purpose. The peat contains 85 to 95 per cent water. It is impracticable to collect from the lower parts of the bog samples of very wet peat which contain the same amount of water as is found in the upper parts of the bed. Experience shows that the peat loses nothing of consequence to its fuel value, or anything that would show in chemical or fuel analyses, if the water is squeezed from it soon after it is taken from the bog. Consequently, all of the samples collected, with the exception of those taken for the identification of plant remains, were squeezed out as soon as sacked, and then allowed to dry until the moisture contents were reduced to about 25 or 30 per cent before they were shipped to the laboratory.

SIMPLE FIELD TEST FOR PEAT FUEL

A simple test, easily made in the field, and frequently used in the work of testing the bogs, is to take a small amount of the peat after the sample is made up and mixed, so that an average is obtained, and work it up well between the hands until the material consists of a thoroughly disintegrated and structureless mass. The more thoroughly the peat is macerated, the more reliable will be the test. When the mass is completely disintegrated, it is pressed between the hands, into a small cake, or briquet, and placed in the sun to dry. After several days, depending upon the weather, the material will be as dry as air-drying can make it. The briquet is then examined as to texture, strength, weight, cohesion, etc. If it is a dense, tough, hard, homogeneous mass, the material will probably make first-class machine peat, unless the ash content is too high. If the briquet is soft, fibrous, weak, and crumbly, it is evidence that difficulties will be encountered in attempts to manufacture it into machine peat fuel.

ESTIMATION OF CONTENTS OF THE BOG

When the area of the bog, and the average depth of the peat are known, it is a simple calculation to estimate the cubic contents of the deposit. The area (in square feet) multiplied by the average depth of peat (in feet) will give approximately the number of cubic feet of peat in the deposit. The quantity of peat available in a given deposit may be estimated with sufficient accuracy in most cases by assuming that at least two hundred tons of air-dry machine peat can be made per acre for each foot in depth.[67] This method has been used throughout the report in estimating tonnages of machine peat.

THE UTILIZATION OF THE MINNESOTA PEAT DEPOSITS

PEAT FUEL

The properties essential to a good fuel peat have been explained at length in Part I, and also the various kinds of fuel which can be made from peat, and the processes and cost of manufacture have been discussed. It is necessary to give here only a statement of the possibilities of utilizing the Minnesota peats for fuel.

Nearly all of the peat deposits in the state contain peat suitable for the manufacture of peat fuel, but not all of the bogs are deep enough to make such an industry pay. The most profitable commercial use which can be made of the peat in Minnesota, is a question of great importance at the present time. 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

[67] Charles A. Davis, *op. cit.* p. 70.

field, especially in the northern part of the state. This industry has been successful in a number of large plants in Europe; and there seems to be no reason why it should not succeed here.

The manufacture of machine peat for domestic and other fuel in Minnesota offers a most attractive field. The character and composition of the peat found in northern Minnesota is remarkably uniform when the immense size of the deposits is considered. The analyses of the peats of the state (pages 76 to 81, inclusive) show that the average ash content of these peats is very low, while the percentages of combustible materials compare favorably with any peat in the world. The presence of such large amounts of peat of excellent quality, situated as many of the bogs are, immediately adjoining railroad tracks and near large and thriving towns, makes it certain that the machine peat industry will develop within a comparatively short time.

GENERAL LOCATION OF THE PEAT DEPOSITS SUITABLE FOR FUEL

The largest and best fuel peat deposits in the state are those in the northern part. The most important are found in St. Louis, Koochiching, Beltrami, Itasca, Aitkin, and Carlton counties, but many hundreds of smaller bogs, containing peat of equally good fuel value, occur in many other counties. Nearly every county in central and northern Minnesota, except the tier of counties along the western border, contains good fuel peat.

The chief advantages of the deposits of the north as sources of fuel are (1) uniformity of texture; (2) uniformity of physical and chemical composition; (3) low ash content; (4) great size of the bogs; (5) even surfaces of the bogs; (6) uniformity of depth of peat over large areas; (7) ease of drainage; and (8) accessibility to railroads.

The deposits in central Minnesota are, as a rule, small as compared to the deposits in the northern counties. These smaller bogs are frequently of the filled-lake type in which the peat is of variable thickness, and of different quality at different depths. A disadvantage which some of these small filled-lake bogs have as possible locations for peat fuel plants, is the difficulty encountered in draining them, for they often lie in hollows or depressions in the drift, without any natural outlet.

In southern Minnesota, peat suitable for fuel is found in Anoka, Hennepin, Ramsey, Dakota, Wright, Meeker, Carver, Scott, Nicollet, Le Sueur, Rice, Brown, Blue Earth, Waseca, Steele, and Freeborn counties. The best and largest bogs in the south are in Anoka, Hennepin, Ramsey, and Blue Earth counties. For descriptions of these peat deposits see the detailed discussion given under the various county headings at the end of this report.

PROXIMITY TO MARKET AND TRANSPORTATION

While some of the great muskeg swamps of northern Minnesota lie far away from any railroad, nevertheless, many of the largest and deepest are crossed by some line of railroad, and many others are in close proximity to a railroad or are touched by a track at some point. There are hundreds of bogs which are crossed by railroad lines and upon which peat fuel plants could be built so as to dispense entirely with any wagon haul, or any construction of extra track other than a siding for the loading of cars.

Wagon roads are already constructed so that most of the bogs in the state, except in the northern counties, are accessible. In Koochiching, Beltrami, Marshall, St. Louis, Aitkin, and other counties in the north, drainage ditches are rapidly being constructed. For several years, the state has been at work upon the problem of draining these swamps and already hundreds of miles of large ditches have been constructed. Such ditches typical of northern Minnesota are shown on Plates XII and XIV. With the digging of the ditches comes the construction of roads. The soil from the ditches is piled to one side and afterward levelled on the top, and a road is thus made along the ditches. Figures A and B, Plate VIII, show roads constructed in this way.

PREPARATION OF THE BOGS FOR MANUFACTURE OF PEAT FUEL

The amount of preparation necessary before a machine peat plant could operate to advantage will vary between wide limits. This is because of the many types of bogs which exist in the state, and which have been already described under "Classifications of Minnesota Peat Deposits," (pages 52 to 61). In many of the open sedge bogs which occur in nearly all parts of the state, practically no preliminary work is necessary, other than drainage. In the open heath bogs, the preparatory work would consist of draining the upper 10 or 12 feet, and smoothing the surface of the bog by the removal of the larger heath shrubs. In the bogs which contain scattered growths of scrub spruce and tamarack, more labor would be required to put the deposit in shape to begin the manufacture of machine peat. Finally, in the case of some of the big tamarack-spruce swamps, the timber, though small, is so thick, and the surface of the bog is so covered with fallen logs and roots, that the expense of clearing preparatory to working the deposit for fuel would be prohibitive.

Much of the preparatory work of draining the bogs has already been done by the state and by the system of judicial district ditches, constructed by special tax levies on the land benefited. These ditches do not drain deep enough to render the bog directly available for agriculture or the establishment of peat fuel plants, but they constitute the main or trunk channels, and only small auxiliary ditches or feeders would be required thereafter in order properly to drain the land. Plate XX shows ditch excavators or dredges of various types at work in the northern Minnesota peat swamps.

POSSIBLE USES OF PEAT IN THE IRON ORE INDUSTRY

Christianson[68] suggests the following possibilities of using peat in connection with the iron ore industry:

1. *The use of peat for power.*—A large amount of low-grade iron ore as mined on the Mesabi Range is now being concentrated. All ore concentrating processes require power, which in Minnesota, at present, is usually obtained from coal. It is possible to generate this power cheaply from peat, as has been demonstrated at numerous localities in Europe. A peat power plant should be located on the bog and should consist of a plant for the manufacture of machine peat; a gas-producer plant for converting this machine peat into producer gas; and gas engines coupled to electric generators for generating electric power. The power thus obtained could be cheaply transmitted from the bog to the mines, whereas the transportation of machine peat in large quantities would be more expensive because of its bulk.

2. *The use of peat for heating operations.*—(a) By burning machine peat directly; (b) by burning peat powder; (c) by burning producer gas derived from machine peat.

In the processes for the beneficiation of iron ores, drying, roasting, calcining, and sintering are often important steps. In all of these operations peat could be used as a source of heat to take the place of coal. The simplest method of burning peat is to use it in the form of machine peat. In Sweden, where peat powder has been successfully used in boiler firing, it is claimed that this form of peat fuel is more economical, and higher temperatures are obtained than are possible when machine peat is used. To offset any such advantages, however, the cost of manufacturing peat powder is considerably above the cost of machine peat. Where the ore is treated in gas-burning furnaces, peat producer gas would make an excellent fuel.

3. *Peat as a binder for ore briquets.*—In some of the deposits of soft hematite ore a large amount of fines must be agglomerated before smelting. Since iron oxide has no plasticity or binding properties, it is necessary to add some binder in order to agglomerate the fine ore. It is suggested that peat may be used as a binder in briqueting these finely divided iron ores. Christianson conducted a series of experiments using 12½, 12¾, and 15 per cent of dry peat with finely divided iron ore, and made the mixture into briquets of the usual type. All the briquets showed remarkable toughness, and retained their shape in a reducing

[68] Peter Christianson, *op. cit.*

A. DITCH DREDGE AT WORK IN SPRUCE SWAMP, BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

B. DREDGE EXCAVATING LARGE DITCH THROUGH A TAMARACK-PEAT SWAMP, BELTRAMI COUNTY
PHOTO BY E. J. BOURGEOIS

C. DIPPER DREDGE EXCAVATING LARGE DRAINAGE DITCH THROUGH AN OPEN PEAT BOG, KOOCHICHING COUNTY
PHOTO BY E. J. BOURGEOIS

atmosphere similar to that of a blast furnace. In an oxidizing atmosphere, however, the briquets soon crumbled because of the small amount of peat used as a binder with the ore. Because of the low ash content of Minnesota peat, only a very small amount of impurities would be introduced into the ore by this process. Assuming a mixture of 85 per cent ore, 15 per cent dry peat containing 10 per cent ash, the total foreign slag-making matter thus introduced into the charge would be only 1.5 per cent.

4. *Possibilities of peat for smelting.*—(a) The use of peat charcoal; (b) the use of peat coke.

The use of peat charcoal to take the place of wood charcoal in the smelting of iron ores does not seem practicable under the present conditions. However, in the electric smelting of iron ore, peat charcoal may be used, when the supply of wood charcoal becomes diminished.

Peat coke would be satisfactory in the smelting industry if it could be produced in a suitable form. At present, peat coke is too soft to compete with coal coke for use in iron ore smelting.

THE AGRICULTURAL POSSIBILITIES OF MINNESOTA PEAT LANDS

There is already a large acreage of peat land under cultivation in the state, and additional areas are being reclaimed each year. The largest bogs of shallow peat (less than 4 feet thick) occur in the northwestern and south central counties. In Roseau, Marshall, Pennington, Red Lake, and western Beltrami counties, in the north; and Freeborn and Blue Earth counties, in the south, there are large areas over which the peat is so shallow that the subsoil could be reached with a deep tiller. Much of this land is already under cultivation, and crops of flax, barley, or oats are raised on it annually. Many square miles of wild meadow hay are cut each year on the peat lands of northern and central Minnesota, and much additional peat land is utilized for pasture all over the state. In practically every county where peat occurs, there are swamp areas which are utilized in some way for agricultural purposes. Even in the big bog tamarack and spruce muskegs of Koochiching, Beltrami, and St. Louis counties, settlers are taking up homesteads of peat land, and on some of these claims the peat is 10 to 15 feet thick. Views of some of these "muskeg farms" are shown on Plate XXI.

Three of the best farms in the northern counties which are situated on peat lands are: the farms of Mr. G. G. Hartley, one of which is at Island, St. Louis County, and the other at Duluth; and the Experimental Farm of the Duluth and Iron Range Railroad Company, at Meadowlands, St. Louis County. The Island farm, and the peat bog upon which it is located, are described on pages 238 to 240, inclusive, and the bog at the Duluth farm on page 222. For a description of the Meadowlands region, see page 224.

The Minnesota Agricultural Experiment Station is conducting experiments to determine the agricultural possibilities of Minnesota peat lands in various parts of the state, and bulletins are to be issued in which the results of these investigations will be given. Those wishing information on this subject may write to the Division of Soils, University Farm, St. Paul, Minnesota. These results are awaited with interest throughout the state, and it is hoped that the experiments may continue on a large scale, for there is no problem more important to the agricultural development of the northern counties of Minnesota than that of the use of the peat swamps in that region.

SOME LIMITATIONS ON THE CULTIVATION OF PEAT LANDS IN MINNESOTA

BY

F. J. ALWAY

The results obtained during the past thirty years at the various European peat experiment stations have fully shown the ability of peat soils, even those of inferior quality, to produce satisfactory crops of forage plants and small grains and all our ordinary vegetables, with the exception of asparagus, when suitable cultivation and proper fertilization are employed, and also when the climatic conditions are favorable. In speaking of successful farming on peat it is always understood that a satisfactory drainage system has been installed—one that holds the water far enough below the surface to prevent water-logging and yet does not lower it to such an extent that the crops suffer from drouth. In regions with a very heavy rainfall, such as 60 to 80 inches per year, it has been found that there is no danger of depressing the water too much, the crop plants doing as well on the sides of ditches 12 feet deep as elsewhere. However, in climates such as we have in Minnesota, the highest yields are obtained with the water at a depth of not more than from 20 to 40 inches. The most favorable depth depends upon the particular crop.

The factors which, aside from climate, place limitations upon the profitable cultivation of peat land, are the cost of labor, of fertilizers and lime, and the transportation facilities, which determine to a considerable extent the actual cost at the bog of the fertilizers and lime, and finally the expense of marketing the products. All of these, except the climate and the character of the peat, are subject to sudden and radical changes.

In many places, and especially on the edge of the Red River Valley, there are considerable areas where the peat is shallow, 8 to 15 inches in depth, and there the land soon after being brought under cultivation acts, so far as crop yields are concerned, like an ordinary black loam.

A. A PIONEER FARM LOCATED IN A LARGE MUSKEG, NORTHERN MINNESOTA
PHOTO BY E. J. BOURGEOIS

B. A MUSKEG "FARM" ON AN OPEN BOG IN NORTHERN MINNESOTA
PHOTO BY E. J. BOURGEOIS

C. WINTER VIEW OF SETTLER'S CABIN AND CLEARING IN A TAMARACK SWAMP
PHOTO BY E. J. BOURGEOIS

However, the extensive areas of the north have in general a depth of from 5 to 10 feet of peat, or even much more, and their treatment should be different from that of the ordinary soils.

As in northern Minnesota there are large areas of wild land with ordinary soil of good quality, the peat can be profitably farmed only where it offers some distinct advantage over the mineral soils. One advantage often is the lower cost of clearing, offset in part by the expense of draining. Another, on the better type of peat, is the abundance of nitrogen. In ordinary soils this constituent is the one most difficult to maintain, while in peat soils there may be sufficient nitrogen for centuries. A third, and probably by far the greatest advantage of all, is the unlimited supply of moisture available at all times on properly drained peat soils. Insufficient moisture is most frequently responsible for low yields of forage crops, even in northern Minnesota. The importance which this advantage of the peat soils may assume is evident, for it is just when the hay and pasture crops on the mineral soils are light, on account of drouth, and the prices for these are high, that the bogs will be producing their heaviest yields.

There are some marked disadvantages shown by these where the peat is so deep that the plants must derive their nourishment entirely from the peat layer. According to European experience all these deep peat soils, at least after a few years of cropping, and commonly in the very first year, require an application of potash. Phosphates also are required by some, and on the poorer types a dressing of lime or ground limestone is needed, and also either a commercial form of nitrogen or the use of legumes as green manures. Stable manure, which is a complete fertilizer, supplies potassium, phosphorus, and nitrogen, and may suffice for any peat, with the possible exception of one requiring a very liberal application of lime, but as it in general can be used much more profitably on ordinary soils its use on peat is to be advised only where the farmer has no ordinary soil, or is producing some crop which brings a very high return per acre, such as celery or lettuce.

As the need for potash may be assumed to apply to all peat soils, while that of phosphates and lime holds for only part of them, I shall confine myself to the potash problem in so far as fertilizers and soil amendments are concerned. The world's supply of potash for the past 50 years has been derived from Germany, and so at present practically none is obtainable. The result is that in the matter of this fertilizer our peat land farmers will be at a great disadvantage compared with those in Germany, Austria, and Sweden, all of whom are convenient to the supply. As a result we must look to that form of farming which requires the smallest application in order to ensure satisfactory returns after the initial dressing of potash. The one removing the least is stock production, or dairy farming. When the crop is pastured very little potash is removed, an annual application of 100 pounds of sulphate per acre having been found sufficient even for heavy pasturage, while twice that amount would be required for an ordinary crop of oats. If the grass be removed as hay and the manure produced from this be returned, a somewhat heavier application of potash would be needed than if it were pastured off.

Another limitation on the profitable cultivation of peat soils lies in the climate. In this we enjoy equal advantages with European countries. These soils are especially subject to summer frosts, which are distinct in origin from those on ordinary soils in low places. Those on the peat occur, not because this occupies the lowest places, but because of its properties. These frosts may be prevented by coating the peat with a few inches of sand, clay, or loam.

The climatic conditions on two bogs which are otherwise similar may be so different as to render crops and practices adapted to one entirely unsuited to the other. Only very rarely do we find a station for weather observations situated on a bog, and the temperature records for one on ordinary soil do not give us information as to the probable occurrence of these summer frosts on the bogs adjacent to the observation station. A good illustration is provided by the data for 1914 obtained at Grand Rapids. Maximum and minimum thermometers were placed in two shelters about 400 yards apart. The one was in the midst of the potato plots on the bog, a foot above the surface of the peat, and about 100 yards from the nearest mineral soil, while the other was on a hill 15 or 20 feet high. Daily readings were made from the 1st of June until the 25th day of September, the date of the first killing frost on the mineral soil. Although temperatures of 29° to 31° were shown on four nights after August 26, no injury to vegetation on the mineral soil was observed until the severe frost of September 25. During this period the thermometer on the bog recorded a temperature below 32° on seventeen nights and on ten of these it was below 29°. Many of these frosts injured the potato vines and tender vegetables would have been killed.

We are not the only people who have to meet the problem of frequent summer frosts. Those at the European peat experiment stations having this problem have been endeavoring to develop methods of meeting it. Theoretically the simplest method is to cover the peat with sand, clay, or loam, in this way presenting to the sky an ordinary or mineral soil. This disposes of the first problem, the night temperatures being similar to those on the surrounding ordinary soil. This method is used very extensively by the land owners in Sweden, but, as an application of from 80 to 320 cubic yards per acre is required, it is not promising here.

Another method of protection is the selection and development of resistant crop varieties. In the case of oats and potatoes this has already much improved conditions for the peat land farmers in those portions of Europe where the bogs are especially subject to summer frosts.

More promising than any other method is the one in which protection is secured by the farmers through the use of their peat soil for the production of forage crops. The grasses and clovers are highly resistant to frost, and when marketed in the form of dairy products or fat cattle reduce the potash requirement to a minimum and at the same time solve the problem of the high cost of transportation. Even in Europe where the large peat areas are more convenient to the supply of potash and to good markets, they are being more and more largely devoted to the production of forage crops.

The question as to whether any particular tract of peat land in Minnesota can, at present, profitably be reclaimed for ordinary farming operations by proper drainage and fertilization, can not now be definitely answered. In central Europe, Germany, and Austria, the officials of the peat land experiment stations are convinced that reclamation is economic in the case of practically all their peat lands. In Sweden there are twelve million acres of peat land compared with a total of less than nine million acres of land of all kinds at present under cultivation. After nearly thirty years of investigational work by the Swedish Peat Land Society, the director of its experiment station believes that only the better class of peat lands, and only the parts of these convenient to transportation, can be profitably reclaimed at present.

OTHER USES OF MINNESOTA PEATS

Peat for fertilizer filler.—As pointed out elsewhere in this report, peat makes one of the best fillers, or diluents, for artificial or chemical fertilizers, because it improves the fertilizer, both mechanically and chemically, and adds to the total nitrogen content of the complete fertilizer. The black and thoroughly decomposed peat is generally preferred for this purpose. In Minnesota, black peat is rare in the north and is found only in the lower portions of some of the bogs. In the southern and south central portions of the state, many shallow deposits of mucky peat exist, the material from which could be used for fertilizer filler, since a moderately high percentage of ash or mineral matter in the peat is no detriment when used for this purpose. Peat fertilizer-filler plants have been operated in eight or ten states, and there is a good field in Minnesota for such an industry.

Peat for stable litter and packing material.—These manufacturers of peat require a strong fibrous material, and hence the deposits best suited to such requirements are the sphagnum or peat-moss bogs. It has already been pointed out that sphagnum was found in large quantities only north of the Twin Cities, and the best and largest bogs of this type occur in Koochiching, Beltrami, St. Louis, Aitkin, Itasca, and eastern Marshall counties. The material in the upper portions of all peat bogs is always less decomposed than that below. Hence the depth of the bog is of secondary importance in seeking peat to be used for litter and packing. The upper 2 to 4 feet of all the sphagnum bogs are usually but slightly decomposed, and frequently the moss is almost perfectly preserved to this depth. There is an enormous amount of excellent peat moss available for litter and packing in the counties named above, and numerous smaller deposits of value are scattered throughout the region in which sphagnum grows. The upper and undecomposed portions of many of the sedge bogs of central Minnesota also will supply good packing material and peat litter.

Peat for paper stock.—The best peat for paper stock to be had in the state occurs in the big, shallow, open bogs of Roseau and Marshall counties and in the smaller, but more numerous sedge bogs in central and southern Minnesota. Since it is necessary to obtain strong, clean, fibrous material for paper stock, the best bogs for such purposes are those composed entirely of successive layers of sedges or grasses. Such peat occurs in large quantities in the localities named.

Peat for woven fabrics.—For the manufacture of woven fabrics the peat should consist of the strongest and longest fibres obtainable. Such peat is only to be found in bogs which have been built up by successive layers of grass-like plants. The deposits best suited to this purpose occur in the northwestern part of Minnesota in Roseau and Marshall counties, and in some of the bogs of sedge and grass peat in the central part of the state. In general, the same localities mentioned as sources of material for paper stock, will supply material suitable to fabric manufacture.

Peat moss for surgical dressings.—Since the beginning of the great war in 1914, peat moss has been used in constantly increasing quantities for surgical dressings. Peat-moss pads are largely displacing cotton dressings in all of the European armies, and hundreds of thousands of these dressings are sent to France by the American Red Cross, to be used in the hospitals and dressing stations of the allied armies. A discussion of the sanitary and medicinal uses of peat and peat moss, with a statement of the desired properties of sphagnum moss for such uses, is given on pages 28 and 29 of this report.

Minnesota contains deposits of sphagnum moss suitable for use in surgical dressings. Some of the more important localities in Minnesota where such sphagnum moss may be obtained are as follows:

Carlton County.—Corona bog: typical muskeg covered with sphagnum moss, comprising an area of several square miles in the region surrounding Corona station on the Northern Pacific railroad (Locality 13, page 135).

Itasca County.—Wawina bog: near Wawina station on the Great Northern railroad (Locality 118, page 165); Deer River bog: 5 miles north of Deer River (Locality 119, page 165); Coleraine bog: 1 mile west of Coleraine station, along Great Northern railroad (Locality 121, page 167); Warba bog: about 2 miles northwest of Warba along Great Northern railroad (Locality 146, page 168); Cohasset bog: about one half mile northwest of Cohasset on Great Northern railroad (Locality 148, page 169).

Koochiching County.—Margie bog: about 8½ miles southwest of Margie along the Minnesota and International railroad (Locality 168, page 175); Little Fork and Nakoda bogs: between stations of same names on the Minnesota and International railroad (localities 198 to 203 inclusive, pages 178 to 181, inclusive); Wisner bog: sections 35 and 36, northeast of Wisner along the Minnesota and International railroad (Locality 204, page 182).

Pine County.—Good sphagnum moss for surgical dressings may be obtained in a bog comprising about 300 acres, near the station of Kerrick.

St. Louis County.—Floodwood bog: near Floodwood station on Great Northern railroad (Locality 10, page 227); Island bog: near Island, on Great Northern railroad (Locality 11, page 238); Elmer bog: near Elmer station on the Duluth, Missabe and Northern railroad (Locality 8, page 226); Wallace bog: near Wallace station on the Duluth, Missabe and Northern railroad (Locality 9, page 228). About 30 square miles in the region surrounding Wallace is covered by sphagnum peat. Duluth bog: very large species of sphagnum moss suitable for surgical dressings occur in a typical muskeg, about 10 miles north of Duluth (Locality 2, page 222).

RÉSUMÉ OF USES OF MINNESOTA PEAT

The principal value of the peat lands of Minnesota, for the immediate future, will probably be found in their use for agricultural purposes. The great areas of easily drainable, shallow peat lands in the northern part of the state constitute an agricultural asset the importance of which is not yet fully realized by many. As pointed out elsewhere in this report, the use of peat land for agricultural purposes is subject to more or less sharp limitations. Nevertheless, it is safe to predict that the next ten or twenty years will see large areas of such lands reclaimed for farms.

For the manufacture of machine peat fuel there is no better raw material in the United States than that which occurs in the Minnesota peat bogs. This industry may be slow to develop in the United States because of our enormous resources of excellent coal. It seems inevitable, however, that at some future date the peat fuel industry will assume considerable importance in America, and when such a time comes, Minnesota peat will be in demand because of its excellent quality, its high fuel value, and its great abundance.

The manufacture of producer gas from machine peat, and the use of this gas to generate electric power seems to offer especially good opportunities to those interested in the development of the peat resources of this country. Minnesota has many millions of tons of peat highly suitable for this purpose.

There are large quantities of peat easily available which could be used for peat litter, mull, packing, or as a fertilizer filler. There is already a considerable market in the United States for these products.

The uses just mentioned probably offer the best opportunities for a profitable peat industry in Minnesota, although, with the development of any one or more of these, markets may be found for by-products and other peat products.

PART III

DESCRIPTION OF LOCALITIES BY COUNTIES

AITKIN COUNTY

Aitkin County has an area of 1,209,600 acres of which 1,078,400 acres are land, and 131,200 acres are water. The area of swamp lands (i.e. peat lands) in the county is approximately 529,880 acres, or 827.93 square miles.[69] Not all of this swampy area contains peat in workable quantities, but probably 75 per cent of the swamps are covered by peat at least 5 feet thick, and over large areas the peat is 9 or 10 feet thick. With an estimated area of 397,350 acres of peat, (three fourths of the total swamp area) of an average thickness of 6 feet, thetotal quantity of air-dried machine peat available is 476,820,000 tons.

The larger part of these great swampy areas will probably be used for agricultural purposes, and the draining of the swamp lands of the county will be rendered comparatively easy because of the good surface slopes which prevail in most parts of the county, and the occurrence of numerous lakes and water courses which could be used as outlets for the water.

The largest and deepest swamps and bogs are in the northern and eastern parts. In the north, the big muskeg swamps of southern Itasca County extend southward into Aitkin County, across two tiers of townships, while in the northeastern part of the county the big muskegs belong to the same immense swamps which cover hundreds of square miles in southwestern St. Louis County. A large muskeg, embracing 75 to 100 square miles, lies north of the town of Aitkin, in the west central part of the county, and several other large swamps occur around the north shore of Mille Lacs Lake, and extend from there northeastward. In addition to these large peat deposits, hundreds of other bogs, some of them several square miles in area, occur widely scattered in the county.

About 60 per cent of the peat deposits are of the open marsh type. The remaining 40 per cent are typical muskeg swamps, and the vegetation consists chiefly of tamarack, spruce, heaths, and sphagnum. The large open bogs, of both the heath and sedge-grass types, occur chiefly in the north central portion of the county, especially around Palisade and Bain. The heaviest timber is in the southern part of the county.

Descriptions of the several bogs which were tested and sampled are given below. These may be taken as typical of the peat deposits in the county.

[69] Geo. A. Ralph, Engineer's Report on Topographical and Drainage Survey. Minnesota. 1906.

Locality 17.—Old tamarack swamp, now a hay meadow, three miles north of Aitkin. The bog embraces an area of about 24 square miles and occupies parts of T. 47N., R. 26W.; T. 47N., R. 27W.; T. 48N., R. 27W.; T. 48N., R. 26W. It extends about 10 miles north of Aitkin on both sides of Willow River. Only a small portion of the south end of the bog was sampled. The region where the samples were taken has all been cleared, drained, and much of the land has been plowed. Hay and oats were growing on this peat land at the time of sampling. Samples were taken from the sides of a drainage ditch which parallels the road extending along the south edge and diagonally across section 1 to the northeast.

Originally tamaracks were numerous on the southern part of this bog, just as they are now at the north end. Buried stumps and logs indicate that this hay meadow was originally a tamarack swamp. The bed is underlain by sticky, yellowish to bluish clay, alternating with areas of bluish quartz sand. The deposit has probably formed on an old outwash plain.

The thickness of the peat where sampled varies from 3 to 6 feet with an average of 4 feet. The original thickness before draining was probably from 7 to 8 feet. The peat where sampled is spongy, fibrous, compact, and firm. It is dark brown in color. Near the bottom of the deposit it is more decomposed. It is composed of moss on top, with sedge, grass, and heath remains below.

Samples were collected every ¼ mile along a ditch at the roadside, for a distance of 2½ miles, and were all mixed in a sack. It was not necessary to bore any test holes as the entire thickness of the peat was exposed on the sides of the ditch.

Analysis 1 (page 76) represents this sample. It shows the peat to be higher in ash than most of the peats in northern Minnesota, but this is probably due to the fact that silt and sand have contaminated the peat exposed in the sides of the drainage ditch. The peat in this bog is also unusually high in nitrogen. The land with proper drainage will probably be more valuable for agricultural purposes than for peat fuel.

SWATARA

Locality 54.—Small bog 4 miles south of Swatara along the line between secs. 5 and 6 T. 50N., R. 26W. This bog contains about 300 acres of shallow peat which has an average thickness of 3 to 4 feet. The peat is brown and earthy and is unfit for the manufacture of peat products. Therefore no analysis was made.

BAIN

Locality 154.—Bog 1¼ miles northwest of Bain on the Moose Lake-Plummer branch of the Soo railroad. The vegetation consists chiefly of dead tamaracks, some heaths, sedges, and grasses. The bottom is evidently a built-up deposit on a rather flat lowland surface. The peat is underlain by hard pebbly clay.

The bog contains an area of 4 to 5 square miles, and connects to the northeast with a large bog with an area of many square miles. The average thickness along the railroad where the samples were taken is only 1 or 2 feet. The peat is dark brown in color, and consists chiefly of the remains of sedges and grasses. The texture is very uniform and the peat is more decomposed than one would expect in such a shallow deposit. Only two holes were put down; the first ¼ mile southeast of the margin of the bog; the second ¾ mile northwest of No. 1 at mile post 291.

Analysis 5 (page 76) represents this deposit. A well-kept farm is located in the middle of this bog. Hay fields and truck gardens were in excellent condition. The peat is too shallow at this locality to be available for fuel, but other portions of the bog could be used for agricultural purposes.

Locality 155.—Bog about 500 feet northwest of Bain railroad station at mile post 189, and extending to mile post 190 along railroad tracks. The vegetation of this bog has changed recently. Moss peat is found within a few inches of the surface, and yet there is little or no moss now growing on the surface. The marsh is covered almost entirely with sedges and grasses. A few heath shrubs grow on the extreme west edge of the bog.

The area of the bog at this locality is about 1 square mile, but it connects to the northeast with a large area of several square miles. The average thickness where these samples were taken is 6 feet with a maximum of 9 feet. The peat is of a light brown, mossy variety in the upper 3 feet of the deposit; the next 2 feet are more decomposed, while near the bottom the material is dark brown, thoroughly decomposed and plastic. The upper layers consist chiefly of moss and heath remains. The center portion is mostly sedge-peat, while the bottom layers contain remains of sedges, cattails, and rushes.

The locations of the test holes are as follows:

Hole 1—At State ditch ¼ mile northwest of Bain; thickness 9 feet.
Hole 2—¼ mile northwest of No. 1; thickness 5 feet.
Hole 3—¼ mile northwest of No. 2 and ¼ mile southeast of edge of bog; thickness 3 feet.

Analysis 6 (page 76) represents this peat. The bog is well located with respect to shipping facilities, and is exceptionally well drained.

PALISADE

Locality 156.—Bog 1 mile southeast of Palisade station along Soo railroad tracks. It is an open grass marsh, probably built up on a flat, undrained area. The vegetation consists chiefly of grass and sedges with a few scattered shrubs. The peat lies upon a flat surface of glacial clay. It consists chiefly of sedge and grass remains, but at hole No. 2 there is about 1 foot of sphagnum peat near the top. The peat is dark brown, fibrous, and poorly decomposed. This bog embraces many square miles and covers most of Morrison and Fleming townships and parts of Jevne township. The peat is shallow in the portion of the bog which was sampled, the average thickness being only 2 to 3½ feet.

The locations of the test holes are as follows:

Hole 1—¼ mile from northwest margin. Mile post 280, Soo railroad tracks; thickness 1 foot. In a hay meadow.
Hole 2—¼ mile southeast of No. 1 along railroad track; thickness 3½ feet. Top 2 feet entirely of sphagnum. Sedges and grasses below.
Hole 3—¼ mile southeast of No. 2; thickness 1 foot. No sedges or moss.
Hole 4—½ mile southeast of No. 3 at mile post 279; thickness 1½ feet. Some reeds and cattails.
Hole 5—¼ mile southeast of No. 4, and ¼ mile northwest of an island; thickness 2 feet. Top peat lighter in color.

Analysis 7 (page 76) represents this sample. The peat is much deeper in the southwest part of the bog where it will average 6 feet or more, but this region is inaccessible at present. In the locality of Palisade wild bay is cut on the bog every year, and large quantities were being harvested at the time of making this examination.

Locality 157.—This represents a portion of the same bog as Locality 156, but the sample was taken further to the southeast about 2¾ miles southeast of Palisade. The vegetation here consists chiefly of sphagnum and polytrichiem moss, heath shrubs, sedges, and a few scattered dead tamaracks. The bog has evidently changed somewhat in character recently as is evidenced by the dying out of the tamarack trees, and the increase of sedges. The deposit has been built up on a flat surface and is not a filled lake.

The average thickness of the peat in this part of the bog is about 4 feet. The test holes showed a maximum thickness of 8 feet. The peat is light brown, poorly decomposed, and fibrous in the upper 3 feet. Below that depth it is darker in color and more decomposed. The entire deposit shows stratification. The peat is composed chiefly of the remains of grasses and sedges.

The location of the test holes is as follows:

Hole 1—Mile post 278, Soo railroad tracks; thickness 5 feet. Light brown sedge-peat. No moss.
Hole 2—¼ mile southeast of No. 1 along track; thickness 3 feet. Light brown, sedge-peat. No moss.
Hole 3—¼ mile southeast of No. 2 along track; thickness 2½ feet. Light brown sedge-peat. No moss.

Hole 4—¼ mile southeast of No. 3 along track; thickness 2½ feet. Light brown sedge-peat. No moss.

Hole 5—¼ miles southeast of No. 4 at mile post 277; thickness 8 feet. Peat uniform in texture.

Analysis No. 8 (page 76) represents this sample. This portion of the bog is very well drained. The surface is flat and smooth and would make good farm land, especially where the peat is only 2 or 2½ feet deep. The peat is firm and would easily support a wagon.

Locality 158.—This represents another part of the same bog as No. 156 and 157, but the sample was taken farther to the southeast. About 4¼ miles southeast of Palisade along the Soo railroad tracks.

The vegetation here consists of tamaracks (mostly dead), heath shrubs, sphagnum moss, and sedges. The peat has been built up on a flat surface of a glacial drift.

The thickness of the peat here as shown by the test holes varies from 1 to 7 feet with an average of 5 feet. The peat is well decomposed, dark brown, and plastic, with more fibrous peat on top. It is composed chiefly of sedges with the remains of reed-grass, cattails and bulrushes.

The location of the test holes is as follows:

Hole 1—At mile post 276¾ Soo railroad tracks; thickness 6 feet. Fibrous peat. Uniform texture.

Hole 2—At mile post 276½ Soo railroad tracks; thickness 1 foot.

Hole 3—At mile post 276¼ Soo railroad tracks; thickness 1½ feet.

Hole 4—At mile post 276 Soo railroad tracks; thickness 2 feet.

Hole 5—At mile post 275¾ Soo railroad tracks; thickness 6 feet. Well decomposed, dark brown peat at bottom.

Hole 6—At mile post 275½ Soo railroad tracks; thickness 7 feet.

Analysis 9 (page 76) shows the composition of the peat at this locality.

AXTELL

Locality 159.—This bog which is a built-up deposit, the surface of which is only about 1 foot above the level of Round Lake, lies 1½ miles east of Axtell along the Soo railroad tracks. The vegetation of the bog consists mostly of sphagnum moss, although considerable polytrichiem moss has appeared on the higher spots or humps, and on the burned areas. Numerous tamarack stumps are present, and a few scattered scrub tamaracks are still growing on the bog. One open portion of the area where there is standing water on the surface, supports only a heavy growth of sedges.

The area of this bog is about 360 acres, and the average thickness as shown by the test holes is 5 feet with a maximum of 7 feet. The top 3 feet of the deposit is fibrous, light brown peat which becomes darker at depth and more decomposed; near the bottom it is very dark brown. Portions of the bog have been burned. The upper 3 feet of peat is composed of sphagnum moss, with many roots and woody parts of heath shrubs. Below this depth, there is a layer of sedge-peat with remains of bulrushes, reeds, and twigs. Near the bottom the peat is composed mostly of sedge remains.

Two test holes were put down as follows:

Hole 1—¼ mile southeast of northwest margin, along railroad; thickness 7 feet. A small island lies just west of hole.

Hole 2—¼ mile southeast of No. 1 along railroad, and ¼ mile from southeast margin.

No analysis was made of this sample. There is one deep spot in the bog where the peat is 14 feet in thickness. This is about 500 feet from the southeast edge of the bog and is a circular area only about 30 feet in diameter, which probably represents a small filled pond.

LAWLOR

Locality 160.—Bog 1½ miles northwest of Lawlor along Soo railroad, in T. 47N., R. 23W., secs. 14, 15, and 22. The bog represents a combination of a filled depression or pond upon which the moss peat has been built up by successive growths. The vegetation is chiefly polytrichiem moss, but sphagnum is noted in the wetter places.

The bog contains an area of about 1 square mile. The average thickness is 3 to 4 feet with a maximum of 7 feet. The peat is brown in color, fibrous, and decomposed in the lower portion of the deposit. The top 3 feet consist chiefly of sphagnum remains. Below this peat is a mixture of the remains of sedges, reed-grass, heaths, and roots.

The location of the test holes is as follows:

Hole 1—At mile post 264, Soo railroad; thickness 2½ feet. Very fibrous.

Hole 2—¼ mile northwest of No. 1 along railroad; thickness 5 feet. Light brown on top. Darker below.

Hole 3—1,000 feet northwest of No. 2 along track about 400 feet from margin of bog; thickness 7 feet. Sphagnum on top. Sedge-peat below.

Analysis 11 (page 76) represents this peat.

McGREGOR

Locality 161.—This bog is three fourths of a mile southeast of McGregor along the Soo railroad. It is an open sedge marsh, probably built up on a flat, undrained surface. The vegetation of the bog consists mostly of sedges and grasses. There are a few patches of bulrushes and scattered groups of scrub tamaracks. The peat lies upon coarse sand which in turn rests upon glacial clay.

The bog comprises an area of about 10 square miles, but the railroad along which the sample was collected crosses only the extreme eastern portion of the area. The bog extends westward and covers most of the north half of Davidson Township. The average thickness along the railroad track is about 3 feet. The maximum depth as shown by the sample is 7 feet. The bog is deeper to the west, and the average of the entire deposit is probably 5 feet or more. The peat is dark brown in color, well decomposed, and uniform in texture from top to bottom. It consists chiefly of sedges with remains of cattails, bulrushes, reed-grass, and parts of heath shrubs and tamarack wood.

The test holes were located as follows:

Hole 1—¼ mile southeast of mile post 268 along railroad; thickness 3 feet. Has been burned.

Hole 2—At mile post 268 along railroad; thickness 3 inches. Has been burned.

Hole 3—¼ mile northwest of No. 2 along railroad; thickness 3 feet. Dark brown, well decomposed peat.

Hole 4—¼ mile northwest of No. 3 along railroad; thickness 2½ feet. Has been burned.

Hole 5—¼ mile northwest of No. 4 along railroad; thickness 5 feet.

Hole 6—At mile post 269, ¼ of a mile from northwest edge of bog; thickness 7 feet. Well decomposed, dark brown sedge peat.

No analysis was made of this sample.

Locality 162.—Bog along Northern Pacific railroad tracks extending northeast and southwest from McGregor. The area is a typical peat marsh which is formed on a glacial outwash plain. The vegetation growing on the bog consists principally of sedges and grasses with a few heath shrubs. The peat is underlain by coarse sand and clay.

The area of the bog is about 3 square miles. The peat is very shallow, the average thickness being about 1 foot. The peat is of dark brown color and is fibrous or spongy. It consists chiefly of sedge and grass remains, with an upper layer of sphagnum in some places.

The location of the test holes is as follows:

Hole 1—½ mile east of McGregor along Northern Pacific railway; thickness 1 foot.

Hole 2—¾ mile east of McGregor along Northern Pacific railway; thickness 1½ feet.

Hole 3—1 mile east of McGregor along Northern Pacific railway; thickness 1 foot.

Hole 4—1¼ miles east of McGregor along Northern Pacific railway; thickness 1½ feet.

Hole 5—½ mile west of McGregor along Northern Pacific railway; thickness 1 foot.

Hole 6—¾ mile east of McGregor along Northern Pacific railway; thickness 1½ feet.

Hole 7—1 mile east of McGregor along Northern Pacific railway; thickness 1 foot.

Analysis 13 (page 76) represents this sample. The portion of the marsh around McGregor is under cultivation and hay is being harvested from most of the area. Some of the ground has been plowed, and corn and vegetables are raised. Numerous low, flat islands, upon which the farm houses are built are scattered over the marsh. These islands of sandy clay are covered with hardwood timber.

TAMARACK

Locality 163.—Bog ¾ mile east of Tamarack station on the Northern Pacific railway. This bog embraces an area of 8 or 10 square miles, and occupies most of the north half of Clark Township. The village of Tamarack is situated on an island south of the center of the bog. The Northern Pacific railway tracks cross the full width of the bog from east to west.

The bog is a combination of the filled-lake and built-up types. The vegetation is mixed. Sedges and grasses predominate at the east side of the bog, while swamp birch and swamp willows are numerous at the west side. Bulrushes, cattails, sedges, and grasses are also prominent. Groups of tamarack trees, some of which are 3 or 4 inches in diameter are scattered over the bog. The peat is underlain by clay which in turn is underlain by coarse sand.

This sample represents the portion of the bog east of Tamarack. The peat there averages 16 feet thick or more; the maximum depth could not be determined, because the 20-foot sampling rod was not long enough to reach bottom. To the west of Tamarack the peat is shallow. (See Locality 164.) The upper 2 feet of the deposit contains dark brown, poorly decomposed peat. From 2 to 10 feet the peat is light brown in color and more decomposed. From 10 to 14 feet the peat is greenish. From 14 to 16 feet there is a layer of dark, well decomposed peat. The main body of the deposit is composed of sedge and grass remains, with a few branches and roots intermingled. Bulrushes, reed-grasses, and other aquatic plants are prominent in the lower part of the deposit. The upper portion of the bog contains many roots and burned logs.

The location of the test holes is as follows:

Hole 1—1,000 feet from eastern margin along railroad track; thickness 9 feet, top 3 feet sedges; middle 2 feet, contains many heaths; bottom 4 feet contains sedges, rushes, and reeds.

Hole 2—¼ mile west of No. 1 at mile post 60 along railroad; thickness 20+ feet. Could not reach bottom. Lower portion is distinctly green.

Hole 3—¼ mile west of No. 2 along railroad track; thickness 14 feet. Lower portion green peat. Coarse sand bottom.

Hole 4—¼ mile west of No. 3 along railroad track; thickness 16 feet. Lower portion green peat. Clay and sand bottom.

Hole 5—700 feet west of No. 4 along railroad track; thickness 17 feet. Lower portion green peat.

Analysis 14 (page 76) represents this sample. Two large drainage ditches (10 by 10 feet cross-sections) cross the bog. The peat is unusual in that no sphagnum was recognized. The numerous tamarack logs and roots throughout the upper 6 feet of the deposit indicate it was once a typical muskeg swamp. None of the bottom green pond peat was included in the sample taken for fuel analysis. This deposit is favorably situated for development and contains an enormous quantity of fuel peat.

Locality 164.—The sample is from the western portion of the same bog as Locality 163. Test holes were started ¼ mile west of Tamarack station along the Northern Pacific railroad tracks in T. 48N., R. 22W.; secs. 16 and 17.

This part of the bog has been built up on a moist flat surface. There is no pond or lake peat west of Tamarack station. The thickness of the peat in this portion of the bog is not more than 1½ to 3 feet. The peat is slightly decomposed and dark brown in color. It consists chiefly of the remains of grasses and sedges, with reed-grass and bulrushes in some places.

The location of the test holes is as follows:

Hole 1—¼ mile west of Tamarack station. Edge of bog; thickness 3 feet. Sedge-peat with bulrushes.
Hole 2—¼ mile west of No. 1; thickness 1½ feet. Sedges with reeds.
Hole 3—¼ mile west of No. 2; thickness 1 foot. Sedges and grass.
Hole 4—¼ mile west of No. 3; thickness 1 foot. Sedges and grass.
The edge of the bog is 700 feet west of hole No. 4.

Analysis 15 (page 76) gives the composition of this peat.

This bog and that described under Locality 162 are typical of all the peat bogs between Tamarack and McGregor. They are shallow and the land is used for cutting wild hay. The depth of the peat is deceptive since the unbroken marshy surfaces with their scattered growths of tamarack give the appearance of deep deposits. Corn, oats, and other grains are being grown on portions of some of the marshes, and truck gardens are being set out. The large meadow or marsh about 1½ miles west of Tamarack is covered with not more than a few inches of peat, and could easily be reclaimed for farm land.

RED TOP

Locality 226.—Bog 2 miles northeast of Red Top on the Moose Lake–Brooten branch of the Soo railroad. This is a burned muskeg. According to old residents, the burning occurred 27 years ago. There are a few small 2-inch tamaracks present, most of which have been killed by fire. Sphagnum and polytrichiem moss and heath shrubs are commonest. Of the heaths, Labrador tea, *Chamaedaphne calyculata*, and *Andromeda glaucophylla* predominate.

The bog occupies several square miles, and the average thickness of the peat as indicated by the test holes is about 4 feet. The peat is firm, fibrous, stratified material of a brown color. The upper portion contains sphagnum, but below 1 foot in depth the peat is composed chiefly of sedges and reed-like plants. At the bottom of the deposit is a thin layer of charred material indicating a fire in the early history of the bog.

The location of the test holes is as follows:

Hole 1—Mile post 205½; ¼ mile southwest of edge of bog; thickness 3 feet.
Hole 2—Mile post 205¼; thickness 6 feet.
Hole 3—Mile post 205; at ditch; thickness 3½ feet.
Hole 4—Mile post 204¾; thickness 4 feet.
Hole 5—Mile post 204½; thickness 4 feet.
Hole 6—Mile post 204¼; thickness 5 feet.

Analysis 16 (page 76) shows the composition of this peat. The bog is clear of trees, and the surface is smooth. The peat is firm, and may be dug in slabs or chunks which retain their shape. The Soo railroad crosses the bog which has already been drained. The locality offers a favorable site for the development of a peat fuel factory.

ANOKA COUNTY

Anoka County lies only a few miles north of Minneapolis and St. Paul, and because of its location the peat deposits in the county deserve special consideration. There is an area of more than 50 square miles of swamp land, most of it covered with peat. The peat deposits are: (1) open sedge-grass marshes, and (2) tamarack swamps. The sedge marshes contain the most and best peat. The tamarack swamps are small, as a rule, and of relatively little commercial value, although a few of these contain deep workable peat. However, since these would require clearing and levelling preliminary to the development of any peat manufacturing industry, it seems probable that they will not be utilized while there are such large areas of open level bog, containing excellent fuel peat, available in the vicinity.

The peat deposits occur chiefly in the central and northern parts of the county. The largest and best deposits are in the so-called "wire-grass marshes" in the south central part, particularly in T. 31N., R. 22W.; T. 31N., R. 23W.; T. 32N., R. 22W.; and T. 32N., R. 23W. In addition to these areas, there are many smaller bogs around the numerous lakes in the southeastern and northern parts of the county.

These open marshes contain clean, well-decomposed peat of excellent quality, of an average thickness of about 7 to 8 feet. The marshes are crossed by good wagon roads, and by the Duluth branch of the Great Northern railroad, which runs through the center of the county, and passes a few miles to the west of some of the largest peat bogs. The exact locations of the swamps and marshes in the south half of the county are shown on the topographic atlas sheets of the Anoka, Minnesota, and White Bear, Minnesota, quadrangles, published by the United States Geological Survey.

It is probable that, because of the proximity to a large market, and because of the excellent quality of the peat in these deposits, the Anoka County bogs will be among the first to be developed when attempts are made to manufacture machine peat for fuel in Minnesota.

At present, these marshes are used as a source of "grass" (sedges) by the Crex Carpet Company of St. Paul, for the manufacture of grass carpets and rugs. A large quantity of wild hay is cut each year from the areas, and drainage ditches have already been constructed through the larger marshes, so that future development will present few difficulties.

The following descriptions of some of the bogs, and analyses of the peat, may be taken as typical of many square miles of peat land in this region.

ANOKA

Locality 142.—Bog 3 miles northeast of Anoka along drainage ditch 1 mile east of Great Northern railroad tracks, T. 31N., R. 24W.; sec. 14. This is an open sedge-grass marsh of the "high-moor" type. The peat is underlain by sand. The original vegetation which consisted of sphagnum, cattails, rushes, etc., has given way to sedges, grasses, swamp shield ferns, small willows, and other species.

The bog comprises an area of about 200 acres of workable peat. The average thickness is 5 feet with a maximum of 7 feet. The deposit, which is well stratified, is brown in color, and mossy or fibrous. It is composed chiefly of sphagnum on top, with remains of bulrushes, cattails, sedges, etc., below.

Samples were taken every 100 feet along the drainage ditch across the bog, and all mixed together in a sack, and an average sample thus obtained. Analysis 17 (page 76) represents this sample. The peat is typical of many small bogs in this part of the county.

Locality 143.—Bog about 2 miles east of Anoka along road on line separating secs. 3 and 4 from secs. 9 and 10, T. 31N., R. 24W. This is a built-up bog covered with vegetation consisting mostly of sedges (*Carex*), grasses, and swamp ferns. There is no sphagnum. The peat is underlain by coarse sand.

The area of the bog is about 800 acres, and the average thickness of the peat as shown by the test holes is 7½ feet. The peat is dark brown, decomposed, but somewhat fibrous. It is made up chiefly of sedge remains.

Test holes were put down as follows:

Hole 1—Near west edge of bog, at roadside; thickness 6 feet.
Hole 2—Near ¼ corner secs. 4 and 9; thickness 8 feet.
Hole 3—Near bridge across creek, 1,000 feet east of No. 2; thickness 7 feet.
Hole 4—About 1,000 feet east of bridge; thickness 8 feet.

Analysis 18 (page 76) represents this sample.

The marsh is especially well suited to the manufacture of peat fuel. No clearing is necessary and the area is already fairly well drained.

Locality 144.—Bog 9 miles east of Anoka along the same road as described in Locality 143. This locality represents a part of an immense "wire-grass" marsh covering many square miles. It is a built-up deposit and not a filled lake. The peat is underlain by coarse sand. The vegetation growing on the bog consists chiefly of sedges (*Carex*), cattails, ferns, reed-grass, and small swamp-willows. The average thickness of the peat at this locality is about 7 feet.

The location of the test holes is as follows:

Hole 1—¼ mile east of southeast cor. sec. 5, at roadside. Near edge of bog; thickness 7 feet.
Hole 2—¼ mile east of No. 1; thickness 9 feet.
Hole 3—¼ mile east of No. 2; thickness 3 feet.
Hole 4—½ mile east of No. 3; thickness 7 feet.
Hole 5—1,000 feet east of No. 4; near island; thickness 8 feet.

Analysis 19 (page 76), represents the composition of the peat in this part of the bog. This marsh has not been well drained, but additional drainage ditches could easily be excavated. The surface is smooth, level, and free from timber, and the deposit offers exceptional opportunities for the development of a peat fuel plant.

Locality 145.—Bog 13 miles east of Anoka at roadside along south edge of sec. 6, T. 31N., R. 22W. This is another portion of the same big "wire-grass" marsh described in Locality 144. This is an open, grass-sedge marsh of the built-up type. The vegetation consists mostly of sedges and grasses. Where surface water is standing on the bog, cattails and bulrushes are common. Swamp ferns and swamp-willows also are numerous. The peat is underlain by coarse gravelly sand.

The average thickness of the peat in this portion of the marsh is 6½ feet. It is brown, to almost black, well decomposed, and rather fluid in the lower portion of the deposit. The peat is made up chiefly of the remains of sedges, bulrushes, cattails, and reed-grass.

Location of the test holes is as follows:

Hole 1—Roadside, southwest corner sec. 6; thickness 7½ feet.
Hole 2—¼ mile east of No. 1; thickness 7 feet.
Hole 3—¼ mile east of No. 2; thickness 5½ feet.

Analysis 20 (page 76) shows composition of the peat in this part of the bog. The area will require more drainage before it can be used for either peat fuel manufacture or for agricultural purposes. This drainage may easily be accomplished, and the locality offers excellent opportunities for the development of the deposit.

BECKER COUNTY

Becker County contains a land area of 1,308 square miles, of which about 250 square miles (17 per cent) are swampy.[70] Most of the swamp land contains but little peat, and much of it has no peat whatever, but is covered with a black muck in which the proportion of mineral matter is very high. The area of actual peat lands in the county is not more than 15 or 20 square miles, distributed throughout the central part of the county from the northern to the southern boundaries.

A large part of the county (12 townships, or 432 square miles) lies in the White Earth Indian Reservation, and is mostly rolling virgin prairie. This is in strong contrast to the hilly, heavily wooded character of the land in the southern part of the county, and especially around Detroit, the county seat. Within the area of this hilly, morainal topography, and on the adjacent till plains, and outwash gravel plains, there are numerous, small tamarack swamps, and open grass-sedge bogs. Many of these represent small peat-filled lakes or ponds. These small swamps and bogs contain most of the workable peat of the county. The following description is typical of these small deposits.

DETROIT

Locality 141.—Bog 2½ miles south of Detroit along the Northern Pacific railway, N.W.¼ sec. 1; T. 138N., R. 41W. This is a small muskeg swamp covered with vegetation consisting chiefly of sphagnum moss, sedges, cattails, heaths, swamp alders, swamp-willows, and swamp spruce. The peat is underlain by sand and muck. The deposit is a typical peat-filled pond in a depression between morainal hills.

The area of the bog is about 12 acres, and the average thickness is about 8 feet. The peat is red-brown, and rather woody on top. Below a depth of 3 feet it consists of greenish to yellowish, fibrous, sedge peat. The bottom 2 feet contain many snail shells. The upper portion of the deposit is composed of the remains of sphagnum, wood fibre, spruce needles, etc. The lower part consists chiefly of the remains of sedges, grasses, and pondweeds.

Only one test hole was put down in this small bog. This was located at the side of the railroad track in the center of the bog.

Analysis 21 (page 76) represents this sample. The bog is too small to be of commercial value for peat fuel. The peat is typical of many of the bogs of southern Becker County, which occupy small pockets in glacial drift, and some of which are large enough for development.

BELTRAMI COUNTY

Beltrami County contains more peat than any other county in Minnesota. It is one of the largest counties in the state, with a land

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[70] Frank Leverett, and U. G. Purssell, *op. cit.* p. 68.

area of 3,822 square miles, of which 2,030 square miles (51.7 per cent) are swamp land. In addition to the 3,822 square miles of land area, there is a water area of about 510 square miles in the lakes of the county. Red Lake, the largest in the state, lies entirely within the borders of the county, and has an area of 408 square miles.

Practically all of Beltrami County north of Red Lake, which includes nearly two thirds of the area of the county, is a great swamp which stretches eastward nearly across Koochiching County, and westward far into Marshall County. This is the largest unbroken muskeg swamp in the United States. The location and extent of this great swamp is shown on the large map of Beltrami County, Plate II, in the pocket at the back of this report. This map shows also the numerous smaller isolated swamps and bogs in the southern part of the county, some of which cover 6 or 7 square miles, containing deep deposits of peat of excellent quality for fuel and other uses. The map (Plate II) shows the surface topography of the northern part of the county, which has been taken from the topographic and drainage map which accompanies House Document 27 of the Sixty-first U. S. Congress, First Session. The field work which was necessary in order to construct the topographic map was done under the most difficult conditions by Mr. Meade and party, for much of the area mapped lies within the great swamp, portions of which are practically impenetrable except in winter. More recently the engineers in charge of the drainage projects now under way have surveyed ditch lines, and put down thousands of test holes and soundings in this great swamp. Much of the data as to the depth of the peat in the area has been placed at the disposal of the writer through the courtesy of the engineers in charge. Thanks are due especially to Mr. W. M. Everts, Mr. O. L. Dent, Mr. E. W. Kibbey, and Mr. E. J. Bourgeois.

Practically all of Beltrami County north of the south shore of Red Lake, and including Red Lake, lies within the limits of glacial Lake Agassiz. The area included within this region constitutes about two thirds of the total area of the county, and includes all of the most important swamps and bogs. The peat deposits of the region are related to the surface of this former lake bed. The surface is flat but not level. The map of the county (Plate II) shows the general slope of the surface of the swamp to be 10 to 20 feet per mile to the northeast. The slope decreases in the northeastern part of the county to less than 10 feet per mile.

The swamps within this area are mostly typical muskegs, timbered with tamaracks and spruce. Within these big muskegs there are numerous open heath bogs with no timber, except, occasionally, a few scattered scrub tamaracks. The peat in the muskegs is variable in depth, but the average thickness in these tamarack-spruce swamps is about 8 to 9 feet. Large areas exist where the peat is 12 to 14 feet deep.

In the western part of Beltrami County some open sedge-grass marshes occur in which no trees are growing. The average depth of peat in these marshes is only 3 or 4 feet.

In the southern portion of the county, south of the limits of glacial Lake Agassiz, the topography is more broken and hilly, due to the existence of extensive moraines. In the basins and depressions between the hills of glacial drift, there are many peat bogs. Some of these are filled lakes, in which the peat is 15 to 20 feet deep. These smaller bogs of southern Beltrami County are of different types. Some are typical muskegs, others are open heath bogs, but the majority are open sedge-grass marshes.

The average depth of the peat in Beltrami County may safely be taken as about 7 feet. It is estimated, on the basis of 200 tons of air-dry machine peat to the acre per foot in depth, that Beltrami County contains a total of 1,818,880,000 tons of air-dry machine peat. Probably half of this amount, or 909,440,000 tons occurs in bogs of workable depth, and is of sufficiently good quality to be available for peat fuel.

BAUDETTE

Locality 15.—Bog 6 miles southeast of Baudette along the Range line road. Samples were collected along the ditch at the roadside. The first sample was taken on the S.W.¼ sec. 18, T. 160N., R. 30W. and additional samples were taken every ¼ mile from there southward for 3 miles.

This deposit is a typical muskeg covered with rather heavy tamarack timber. The vegetation also includes sphagnum, blueberry, bulrushes, and sedges. Very few heaths were noted here. The peat is underlain by yellowish (when weathered) to bluish (when fresh), laminated, sandy clay, which would make good brick and tile. The peat occupies a portion of the bed of former Lake Agassiz. It is a built-up deposit.

This is only a part of an immense swamp which covers most of the northern half of Beltrami County. There are however, many islands of high ground within this area, especially along the streams. (See map of the peat deposits of Beltrami County, Plate II accompanying this report.) In this portion of the swamp, the peat will average only about 4 feet thick, but there is an open bog containing about 4 square miles in secs. 30 and 31; T. 160N.; R. 30W.; and secs. 25 and 36; T. 160N.; R. 31W., where the peat averages 7 feet thick. The peat is dark brown, fibrous, and firm, and contains considerable woody tissue. It is made up chiefly of sphagnum moss with many buried roots, stumps, and logs of tamarack trees.

The samples were collected from top to bottom of the deposit as exposed in the sides of the ditch along the road, and all the samples, taken along a distance of 3 miles, were mixed in a sample sack and an average thus obtained.

Analysis 22 (page 76) represents this sample. A fuel plant could be operated on the deeper part of the bog, but the deposit is at the present time too far from a railroad to be immediately available for peat fuel. Much of the peat is so shallow that the land could be reclaimed for farming.

Locality 197.—Bog beginning 1 mile west of Baudette along the tracks of the Canadian Northern railroad, and extending westward 4 miles. This is a burnt forest-swamp. The recent Baudette fire burned this area completely. The original vegetation included a heavy growth of tamarack and poplar trees. The present vegetation consists of fireweed, sedges, and grasses.

The bog at this locality forms only a portion of an immense swamp which extends southward for 40 miles. The average thickness of the peat at this locality is only 1 foot. The maximum thickness noted was 2½ feet. The peat is dark brown, fibrous, and contains considerable sand in places. The upper portion of the deposit has been burnt. It now consists of woody fibre with the remains of cattails, reeds, etc. No test holes were necessary because the peat is exposed continuously in the side of the drainage ditch along the state wagon road, parallel to the railroad. Samples were gathered in this ditch at regular intervals for 4 miles and mixed in a sample sack.

Analysis 23, (page 76) represents the peat of this locality. The presence of hardwood or deciduous trees as the dominant vegetation on some of these swampy areas around Baudette and Williams, the shallow peat covering, and the very woody nature of this peat indicate clearly that these areas were formerly "woods," and probably dry. It is possible that these woods became converted into swamps through the work of beavers constructing dams, although no direct evidence of beaver work was seen at this place.

WILLIAMS

Locality 16.—Bog 2½ miles northeast of Williams, T. 161N.; R. 33W.; sec. 8. The area is a typical muskeg swamp, the vegetation of which consists chiefly of tamarack, spruce, cranberry, blueberry, pigeon berry, sphagnum moss, and heath shrubs. The peat is underlain by blue to yellow, sandy clay, which is a portion of the old bottom of glacial Lake Agassiz.

The bog contains an area of many square miles and extends north to Lake of the Woods. The land to the south around Williams is higher, and consequently is not swampy. To the east and west the region is swampy with numerous islands of dry ground. The average thickness of the peat at this locality is only about 3 feet. The peat is dark brown to black, well decomposed, and rather fluid, except the top layer, which is mossy and fibrous. It is composed chiefly of sphagnum remains and contains many heath roots and sticks of tamarack wood.

Only one hole was put down at this locality, 200 feet east of the edge of the bog.

Analysis 24 (page 76) represents this sample. The bog at this locality contains no good fuel peat. Much of the area between here and Lake of the Woods could be farmed if the swamp were properly drained.

Locality 194.—This locality, 1½ miles north of Williams, along the range line between sec. 1 of R. 34W. and sec. 6 of R. 33W., represents the south edge of a big swamp which extends north to Lake of the Woods.

The bog is probably a burned muskeg. Tamarack (mostly dead), poplars, alders, sedges, swamp shield ferns, fire-weed, and cattails comprise the vegetation growing on the surface. The peat is underlain by clay and sand. The bog contains an area of many square miles. The average thickness of the peat at this locality is only about 3 feet.

The location of the test holes is as follows:

Hole 1—½ mile north of S. cor. secs. described above; thickness 3 feet.
Hole 2—⅛ mile north of No. 1; thickness 3½ feet.
Hole 3—⅛ mile north of No. 2; thickness 3½ feet.
Hole 4—⅛ mile north of No. 3; thickness 2 feet.

Analysis 25 (page 76) shows the composition of the peat in this portion of the bog.

Locality 195.—Two miles north of Williams. Secs. 31 and 32, T. 162N.; R. 33W.; and secs. 5 and 6, T. 161N.; R. 33W. The area forms a part of the same big swamp as Locality 194, which covers many square miles.

The average thickness of the peat in this part of the bog is only 1 foot. The upper portion of the deposit has probably been drained. The peat is underlain here by marly clay.

The location of the test holes is as follows:

Hole 1—½ mile east of northwest corner McDouglass T. 161N., R. 33W.; thickness 1 foot.
Hole 2—¼ mile east of No. 1; thickness 1 foot.
Hole 3—¼ mile east of No. 2; thickness ½ foot.
Hole 4—¼ mile east of No. 3; thickness 1 foot.
Hole 5—¼ mile east of No. 4; thickness 2 feet.
Hole 6—¼ mile east of No. 5; thickness 1½ feet.

Analysis 26 (page 76) represents this sample. The land here could probably be converted into farming land by clearing and draining.

The soil could be plowed into the peat if the area were drained. The cost of clearing would be high because of the dense growth of trees, most of which are now dead but still standing.

Locality 196.—This is another part of the same bog as localities 194 and 195, and it probably represents a burnt spruce-tamarack-cedar swamp. Spruce is the predominating tree. There are also some large tamaracks and small cedars. Most of the moss has been burnt off, but sphagnum was noted. The peat is underlain in some places by clay, and in others by sand.

The average thickness of the peat in this portion of the deposit is about 3 feet. The material is chiefly sedge-peat with a little sphagnum on top. There is no wood burned in this part of the swamp. The peat below the upper burned layer is light brown, fibrous, and stratified, and has undergone but little decomposition.

Test holes were started 2½ miles north of Williams along a north line, and were spaced as follows:

Hole 1—N. cor. secs. 25 and 30, T. 162N., R. 33W.; thickness 2 feet.
Hole 2—¼ mile south of No. 1; thickness 2 feet.
Hole 3—¼ mile south of No. 2; thickness 4 feet.
Hole 4—¼ mile south of No. 3; thickness 3 feet.
Hole 5—¼ mile south of No. 4; thickness 2 feet.
Hole 6—¼ mile south of No. 5; thickness 2 feet.

Analysis 27 (page 76) represents this sample.

UPPER RED LAKE

Locality 103.—This sample is from a portion of an immense peat swamp extending from the north shore of Red Lake northward to Lake of the Woods, with only a few breaks in the swamp where islands occur, or where soil occurs along waterways. These samples and also those from Localities nos. 104-109 inclusive, were collected by Mr. William Everts, district engineer of the drainage project under way in this region. A large portion of this part of the great Beltrami County swamp has been burned and the ash content, as shown in the analysis of nos. 103-110, is too high for peat fuel. This is partially due to the burning of the upper layers of peat, and partly to the fact that some of these samples became contaminated with sand by the inclusion of peat from the bottom of the deposit. If the bottom 2 feet of the deposit is excluded from the sample, the peat from these localities will carry less than 15 per cent of ash, and will make good peat fuel. The locations of all these test holes may be seen on the map, Plate II.

This bog is a muskeg of the built-up or "high-moor" type. The vegetation consists chiefly of tamaracks, heaths, and sphagnum. The peat is underlain by sand and sandy clay till, which forms a portion of the old bed of glacial Lake Agassiz.

The area of the entire bog covers many square miles. The thickness of the peat is variable, and at this locality the average is 8 feet. The peat is dark brown to yellow brown and fibrous. It is composed chiefly of sphagnum moss with some heath remains.

The locations of the test holes for this sample are as follows:

Hole 1—500 feet north of ¼ cor. secs. 20 and 21, T. 156N., R. 31W.; thickness 10 feet.
Hole 2—500 feet south of cor. secs. 16, 17, 20, 21 T. 156N.; R. 31W.; thickness 7 feet.
Hole 3—800 feet north of above corner, T. 156N.; R. 31W.; thickness 7 feet.
Hole 4—200 feet south of ¼ cor. secs. 16 and 17, T. 156N.; R. 31W.; thickness 7 feet.

Analysis 28 (page 76) represents this sample.

Locality 104.—This is a portion of the same swamp described under Locality 103. The thickness of the peat at this place is about 8 feet. Two test holes were put down to obtain this sample. One was located 1,300 feet north of the ¼ corner secs. 16 and 17, T. 156N.; R. 31W. The other hole was located at the corner of secs. 8, 9, 16, and 17, T. 156N.; R. 31W.

Analysis 29 (page 76) represents this locality.

Locality 105.—This is another portion of the same bog described under Locality 103.

The test holes for this sample were located as follows:

Hole 1—700 feet north of ¼ cor. secs. 7 and 12, T. 155N.; R. 32 and 33W.; thickness 11 feet.
Hole 2—400 feet south of cor. secs. 1, 6, 7, and 14, 155N.; R. 32 and 33W.; thickness 11 feet.
Hole 3—1,000 feet north of above corner; thickness 11 feet.
Hole 4—¼ cor. secs. 1 and 6, T. 155N.; R. 32 and 33W.; thickness 11 feet.
Hole 5—1,400 feet north of above ¼ corner, T. 155N.; R. 32 and 33W.; thickness 9 feet.
Hole 6—100 feet north of cor. secs. 1, 6, 31, 36, T. 155N.; and 156N.; R. 32 and 33W.; thickness 8 feet.
Hole 7—1,600 feet north of above corner; thickness 9 feet.

Analysis 30 (page 76) represents this sample.

Locality 106.—This is also a portion of the same immense swamp as that described under Locality 103.

The test holes put down to obtain this sample and the thickness of the peat are shown as follows:

Hole 1—700 feet north of ¼ cor. secs. 31 and 36; T. 156N., R. 32 and 33W.; thickness 7 feet.
Hole 2—500 feet south cor. secs. 25, 30, 31, 36; T. 156N., R. 32 and 33W.; thickness 11 feet.
Hole 3—1,000 feet north of above corner; thickness 9 feet.

Hole 4—150 feet south of ¼ corner secs. 25 and 30; T. 156N., R. 32 and 33W.; thickness 11 feet.

Hole 5—1,300 feet south of cor. secs. 19, 24, 25, and 30, T. 156N., R. 32 and 33W. thickness 11 feet.

Hole 6—200 feet north of above corner; thickness 9 feet.

Hole 7—900 feet south of ¼ cor. secs. 19 and 24; T. 156N., R. 32 and 33W.; thickness 9 feet.

Analysis 31 (page 76) represents this locality.

Locality 107.—This is also a portion of the same swamp as that described under Locality 103.

The test holes put down to obtain this sample and the thickness of the peat are shown as follows:

Hole 1—At ¼ cor. between secs. 19 and 24; T. 156N.; R. 32W. and R. 33W.; thickness 9 feet.

Hole 2—1,000 feet south of cor. secs. 18, 19, 13, 24 T. 156N.; R. 32 and 33W.; thickness 8 feet.

Hole 3—500 feet north of above corner; thickness 9 feet.

Hole 4—700 feet south of ¼ cor. secs. 13 and 18; T. 156N.; R. 32 and 33W.; thickness 9 feet.

Hole 5—800 feet north of ¼ cor. secs. 13 and 18; T. 156N.; R. 32 and 33W.; thickness 8 feet.

Analysis 32 (page 76) represents this locality.

Locality 108.—This is also a portion of the same swamp as that described under Locality 103.

The test holes put down to obtain this sample and the thickness of the peat are shown as follows:

Hole 1—800 feet south of cor. secs. 4, 5, 8, 9, T. 156N., R. 31W.; thickness 7 feet.

Hole 2—800 feet north of above corner; T. 156N., R. 31W.; thickness 6 feet.

Hole 3—400 feet south of ¼ cor. secs. 4 and 5; T. 156N., R. 31W.; thickness 7 feet.

Hole 4—1,100 feet north of above corner; T. 156N., R. 31W.; thickness 5 feet.

Analysis 33 (page 76) represents this locality.

Locality 109.—This is also a portion of the same swamp as that described under Locality 103.

The test holes put down to obtain this sample and the thickness of the peat are shown as follows:

Hole 1—200 feet north of cor. secs. 28, 29, 32, 33, T. 157N., R. 31W.; thickness 2 feet.

Hole 2—1,400 feet north of above corner; T. 157N., R. 31W.; thickness 2 feet.

Hole 3—300 feet south of ¼ cor. secs. 28 and 29; T. 157N., R. 31W.; thickness 2 feet.

Hole 4—700 feet north of ¼ cor. secs. 28 and 29; T. 157N., R. 31W.; thickness 3 feet.

Hole 5—1,000 feet south of cor. secs. 20, 21, 28, 29; T. 157N., R. 31W.; thickness 1 foot.

Analysis 34 (page 76) represents this locality.

Locality 110.—Continuation of sampling in same large swamp as described in localities nos. 103-109 preceding. The thickness of the peat at this place is about 6 feet. Only one test hole was put down, located at the corner of secs. 31, 32, 5 and 6 of T. 156N.; and T. 157N.; R. 31W.

Analysis 35 (page 76) represents this locality. The sample shows clean peat without contamination of sand from the bottom of the hole, as in the case of the preceding samples 103-109 inclusive, taken at other localities in the same swamp.

BEMIDJI

Locality 123.—Bog 4 miles southeast of Bemidji, along the Great Northern railroad tracks, in the NE¼ of sec. 35, and SW¼ of sec. 36, T. 146N.; R. 33W. This area is probably a burned tamarack swamp, which has reverted to an open sedge marsh. The peat is underlain by a few inches of black mud, and below that, by coarse sand. The deposit probably represents a filled lake or slough.

The bog extends from about 2 miles southeast of Bemidji almost to Rosby. The total length of the bog is about 3½ miles, and the width is only about a quarter of a mile. This sample represents an area of about 120 acres in the most accessible and workable portion of the bog. The average thickness at this locality is about 8½ feet. The peat is dark brown, soft, well decomposed, fine grained, and of an even texture throughout. There is a little moss peat on top of the deposit, but most of the material is composed of sedges and grasses. A layer of roots, stumps, and logs was encountered at a depth of 6 feet below the surface of the bog.

The test holes were located as follows:

Hole 1—Mile post 94 on Great Northern railroad near west end of bog; thickness 5 feet. Dark brown, decomposed peat.
Hole 2—520 feet east of No. 1 along railroad track; thickness 9 feet. Sedge-peat.
Hole 3—520 feet east of No. 2 along track; thickness 12 feet. Sedge-peat.
Hole 4—520 feet east of No. 3 along track; thickness 10 feet. Sedge-peat.
Hole 5—520 feet east of No. 4 along track; thickness 8 feet. Sedge-peat.

No analysis was made of this sample. The bog is well situated for development. It is close to the town of Bemidji, and is crossed by the Great Northern railroad. The peat is of even texture and of good quality for fuel. The open portion of the bog contains at least 216,000 tons of air-dry machine peat.

Locality 124.—This sample is from a continuation of the same bog as that described under Locality 123, and was taken about 2 miles southeast of Bemidji along the Soo railroad tracks. The vegetation of the bog at this locality consists chiefly of sedges.

There is an area of about 160 acres of open bog at this place, having an average thickness of about 8 feet. The peat is dark brown, plastic, well decomposed, and of even texture. It is made up chiefly of sedge and grass remains.

Test holes were located as follows:

Hole 1—West edge of bog, along track; thickness 6 feet. Dark brown, well decomposed sedge-peat.
Hole 2—Center of bog, 675 feet east of No. 1; thickness 10 feet. Dark brown, well decomposed sedge-peat.
Hole 3—50 feet from east edge of bog; thickness 8 feet. Dark brown, well decomposed sedge-peat.

Analysis 37 (page 76) represents this sample. This portion of the bog is well located for development, but the surface is very wet and the bog would require thorough drainage. There are good railroad and wagon road facilities, and but little clearing would be required.

Locality 175.—Bog 1 mile west of Bemidji station, at mile post 372 along Soo railroad tracks. This is a typical muskeg, the vegetation of which consists of tamarack, spruce, heaths (chiefly Labrador tea), swamp-willow, and grasses. The peat is underlain by coarse white sand. The bog lies in a rather deep depression between morainal ridges of glacial gravel.

The area underlain by good peat is about 120 acres. The average thickness as shown by test holes is 9 feet. The maximum thickness indicated is 11 feet. The peat is light brown to red-brown, structureless, and well decomposed. It consists largely of sphagnum with a large quantity of woody material. Many logs and stumps occur buried in the peat at all depths.

The location of the test holes is as follows:

Hole 1—At mile post 372; 400 feet from west margin of bog; thickness 5 feet. Chiefly sphagnum.
Hole 2—400 feet east of No. 1; thickness 10 feet. Sedge-peat on top.
Hole 3—400 feet east of No. 2; thickness 11 feet. Many buried logs.

Analysis 38 (page 76) represents this peat.

Locality 176.—Bog 4 miles north of Bemidji along Minneapolis, Red Lake, and Manitoba railroad. This is a tamarack-spruce swamp, and the vegetation consists largely of tamarack, spruce, sphagnum, and grasses, with willows and other shrubs scattered over the bog. The peat is underlain by sand. The swamp occurs within the area formerly occupied by glacial Lake Agassiz.

The area of this bog is about 4½ square miles. The average thickness of peat indicated by test holes is about 4 feet. The maximum thickness obtained was 6 feet. The peat is dark brown, well decomposed, and plastic and turns black upon exposure to the air. In the vicinity of the small stream which flows through this swamp, the peat is contaminated with sand and silt. Sphagnum and sedge remains with many buried roots and pieces of wood comprise the material from which the peat is formed.

The test holes were located as follows:

Hole 1—At southeast cor. sec. 20, ¼ mile from edge of swamp; thickness 3 feet. Very sandy.
Hole 2—¼ mile northwest of 1 along road; thickness 5 feet; very sandy.
Hole 3—¼ mile northwest of 2 along road; thickness 4 feet, very sandy.
Hole 4—¼ mile northwest of 3 along road; thickness 5 feet, very sandy.
Hole 5—¼ mile northwest of 4 along road; thickness 6 feet. Sandy.
Hole 6—¼ mile northwest of 5 along road; thickness 4 feet. Clean peat.
Hole 7—¼ mile northwest of 6 (railroad crossing); thickness 3 feet. Clean peat.

Analysis 39 (page 76) shows composition of the peat. The peat in this bog is probably too shallow and sandy to be successfully used as a source of fuel.

Locality 177.—This sample was taken from another portion of the same bog as that described under Locality 176. The average thickness at this place is only 2 feet. Two samples were taken along the State road between S½ sec. 29 and S½ sec. 28, T. 147N.; R. 33W.

The location of the test holes is shown below:

Hole 1—500 feet from north margin of bog along road; thickness 2 feet. Bog is drained here.
Hole 2—500 feet south of No. 1 and 500 feet from south margin; thickness 2½ feet. Peat is fluid.

Analysis 40 (page 76) represents this sample. The peat in this swamp has no value for fuel. Clearing would be expensive, but when once cleared and drained, the land could be used for agricultural purposes.

RED LAKE

Locality 134.—This bog covers many square miles north of Upper Red Lake, and is a portion of an immense swamp which extends over most of the north half of Beltrami County.

The bog is a typical example of the built-up type. The vegetation consists chiefly of tamarack, spruce, sphagnum, and heaths. The thickness of the peat at the point represented by this sample is 12 feet. The upper part of the deposit consists of brown, fibrous peat. The lower layers are well decomposed. The bog has been burned and the upper layers are blackened.

A sample was taken at the corner of secs. 13, 18, 19, and 24, T. 155N., R. 32W. and R. 33W. along drainage ditch No. 14. The peat was collected from the spoil bank of the ditch. The thickness of the peat was exposed in the sides of the ditch, and no test holes were necessary.

Analysis 41 (page 76) shows the composition of the peat at this locality. The high ash content is accounted for by the fact that sandy peat from the bottom layer was included in the sample. The upper 8 or 10 feet of peat in this deposit will show a low ash content.

GRYGLA

Locality 137.—Bog 7½ miles east of Grygla, along ditch No. 11. Sample taken from center of sec. 30 T. 156N.; R. 37W.

This is an open marsh or moor of the built-up type covering many square miles, and extending eastward to Red Lake, and westward into Marshall County. The area contains many islands of dry land suitable for farming. (See map, Plate I.) The vegetation consists largely of grasses, sedges, reed-grass, thistles, and goldenrod. The peat is underlain by pebbly clay-till. The area was formerly covered by glacial Lake Agassiz, and the peat has been built up layer by layer on the old lake bed.

The peat deposits in western Beltrami and Marshall counties are shallow. At this locality the average thickness is only 3 feet. The peat is dark brown, firm, and stratified, and is somewhat flaky when dry. It is composed of the remains of sedges, grasses, and stems and leaves of small shrubs. There is no moss.

No test holes were necessary for this sample since the entire thickness of the peat is exposed continuously along the sides of the drainage ditch where the samples were taken.

Analysis 42 (page 76) shows the composition of the peat in this portion of the marsh. The locality is typical of an immense area of shallow peat marsh in all directions.

Locality 138.—This sample is from another portion of the same big open marsh as that just described under Locality 137, and was taken from the corner of secs. 25, 26, 35, and 36, T. 156N.; R. 37W. and 38W. 6 miles east of Grygla along ditch No. 11. The thickness of the peat at this point is also 3 feet. The thickness is very uniform over the entire area. Samples were gathered along the sides of the drainage ditch and all mixed to obtain an average.

Analysis 43 (page 76) represents this sample. The deposit is too shallow to be used for the manufacture of peat fuel or other peat products. The land will be valuable for agricultural uses when better drained. Already large areas are being farmed.

Locality 139.—Another portion of the same big open marsh as just described. This sample was taken 12 miles east of Grygla along section line between secs. 22 and 23, T. 156N.; R. 37W. At this place the open sedge-grass marsh grades into a tamarack swamp which extends over many square miles toward the east. Sedges and grasses predominate here, but there is some moss (not sphagnum) on the surface of the bog, and also scattered tamaracks, alders, and willows.

The peat is only 1½ feet thick at this place, and consists of brown, fibrous material containing much buried wood.

Analysis 44 (page 76) represents this peat. Samples were gathered from several test holes located along the section line described above. The peat is too shallow here to be of commercial value, but the land could be easily reclaimed for agricultural purposes. A deep tiller would reach the mineral soil beneath the peat. Wild hay was being cut on the marsh at the time of making the examination.

Locality 189.—Very large open sedge-grass marsh in T. 160N.; R. 36W. This sample was taken along the section line between secs. 9 and 10. The area represents a part of the great Beltrami County swamp. In this township alone there are about 30 square miles of peat swamp. The area lies within the limits of glacial Lake Agassiz. The average thickness of the peat where sampled is 4 feet.

Vegetation on the bog consists mainly of sedges, swamp birch, swamp shield-fern, buck-bean, and moss. There are also some scattered small tamaracks, all of which are dead. The marsh is a built-up deposit of the "high-moor" type. The peat which is brown and fibrous is composed chiefly of sedges, with some recognizable remains of cattails and reed-grass.

The locations of the test holes are as follows:

Hole 1—At south edge of timber, on line between secs. 9 and 10; thickness 5 feet.
Hole 2—¼ mile south of No. 1; thickness 4 feet.
Hole 3—¼ mile south of No. 2, on an island.
Hole 4—¼ mile south of No. 3; thickness 3 feet.

Analysis 45 (page 77) represents the peat at this locality. From the south corner of secs. 9 and 10, one can look across many miles of open peat marsh. Water covers the surface of the marsh to a depth of about 1 inch, and this water is covered with a brown, oily scum. Sedges are the dominant plants on the bog. The peat will probably average from 4 to 5 feet deep over many square miles in this township. The bog might be used for peat fuel, but at present it is too inaccessible. Drainage ditches were being constructed at the time of making the examination.

WARROAD

Locality 190.—Portion of the same big peat marsh described under localities 188 and 189. This sample was taken about 20 miles south of Warroad along the section line between secs. 10 and 15, T. 160N.; R. 36W.

The thickness of the peat in this locality is about 6 feet. The top layer is light brown, mossy, and but little decomposed. Beneath this is a layer of yellow brown, fibrous sedge-peat, which, at depth, changes in color to a dark brown, somewhat plastic peat. The material is mainly composed of sedge remains with some moss near the top, and a few reeds, cattails, and small pieces of wood mixed through the deposit. The area was formerly covered by glacial Lake Agassiz, and the peat is underlain by clay silt.

Test holes were located as follows:

Hole 1—¼ mile east of corner secs. 9, 10, 15, and 16; thickness 5 feet.
Hole 2—¼ mile east of No. 1; thickness 7 feet.
Hole 3—¼ mile east of No. 2; thickness 6 feet.
Hole 4—¼ mile east of No. 3; thickness 7 feet.

Analysis 46 (page 77) represents this sample.

BENTON COUNTY

Benton County, situated in the east part of central Minnesota, has an area of about 406 square miles, of which 2,275 acres are covered by water in lakes and ponds. The greater part of the surface of the land consists of rolling or undulating till plains. These are interrupted in the northwest corner by a rather flat area of modified drift, covering about a township and a half. In the southeastern part of the county, a narrow belt of hilly morainal topography extends from northeast to southwest across the undulating till plains.

There are very few peat bogs in Benton County. Most of the region was once covered by heavy timber. The swampy areas, which occupy low depressions in the undulating till plains, or small pockets in the morainic belt, are mostly covered with a peaty muck which contains too much mineral soil to be useful for peat products. There are a few small bogs in the moraines which contain peat of moderate depth. Most of the swamp land can be used for farming after it is drained and cleared.

BIG STONE COUNTY

There are no peat deposits in Big Stone County of sufficient depth or area to merit consideration.

BLUE EARTH COUNTY

Blue Earth County, which lies in the central part of southern Minnesota, about 70 miles south of Minneapolis and St. Paul, contains an area of 776.88 square miles, or 497,201.73 acres, of which 21,619.39 acres are covered by water. The general land surface of Blue Earth County is a rather flat upland plain over which are scattered numerous broad shallow depressions which have become the sites of lakes or marshes. The Minnesota River, which forms the greater part of the north boundary of the county, makes a right angle bend there, changing the direction of its course from southeast to northeast. Along the

Minnesota and its larger tributaries, which flow in steep sided valleys about 150 feet deep, the land is well drained and no marshes occur.

There are numerous peat deposits in Blue Earth County, many of which may be of future commercial value. Some of these marshes are deep peat bogs which represent peat-filled lakes. Others are built-up deposits of the "high-moor" type, which have accumulated on wet, undrained surfaces, rather than in lakes. Many of the existing lakes in the county are bordered by deposits of peat which are rapidly forming around the shores. Some of the deposits sampled were of this type.

The majority of the peat deposits in Blue Earth County occur in the northeast quarter of the county, but there are a few in the northwest part. Practically none exist in the southern row of townships. The soil map of Blue Earth County, by Hugh H. Bennett and Lewis A. Hurst of the Bureau of Soils, U. S. Department of Agriculture, shows the distribution and extent of all the peat bogs in the county.

There are no muskeg swamps (i.e. tamarack-sphagnum-heath bogs) in the southern part of the state. The peat deposits of Blue Earth County are all open grass-sedge bogs or meadows. The average depth of the peat throughout the county is approximately 6 feet.

The Division of Soils, of the Minnesota Agricultural Experiment Station, has tested most of the bogs in Blue Earth County, and much of the data in the following descriptions, as well as many samples, have been supplied by Dr. J. F. Alway. The analyses were made by the U. S. Bureau of Mines.

MANKATO

Locality 99.—Small bog about 5 miles northeast of Mankato on west shore of Eagle Lake. This is an open sedge-grass meadow along the lake shore. The area comprises about 90 acres, and the average thickness of the peat as shown by test holes is 9 feet.

Sedges form the dominant vegetation on the bog, but reed-grass, swamp ferns, and swamp-willows were also noted. The top 3 feet of peat is brown, fibrous material. Below 3 feet in depth the peat is soft, rather plastic, and light brown. It is composed chiefly of sedges and grasses. Remains of bulrushes and roots and leaves of small shrubs were also observed.

Analysis 47 (page 77) represents this sample, which was collected from three test holes equally spaced between the wagon road and a small pond in the middle of the bog. The deposit is located near the Dan Patch railroad, and contains good, clean fuel peat.

Locality 100.—Bog 4 miles north of Mankato and ½ mile west of Eagle Lake. This is a sedge-grass bog of the filled-lake type. A portion of the lake still remains as a small pond in the center of the bog. The vegetation consists chiefly of sedges and grasses.

The area covered by peat comprises about 200 acres. The peat varies in thickness from 4 to 7 feet, with an average of about 5 feet. It consists of brown, well decomposed, but rather fibrous, soft peat. It is composed chiefly of sedge and grass remains, with some recognizable bulrushes and cattails.

Samples were taken by mixing the material from two test holes located near the center of the bog along the road which crosses the bog from north to south.

Analysis 48 (page 77) which represents this peat, shows it to have a high thermal value, with a moderately low ash content, and high content of nitrogen. The deposit contains workable peat of excellent quality for fuel. The bog is situated within ¼ mile of the Chicago and Great Western railroad and requires but little preparation for development.

Locality 101.—Bog 7 miles northeast of Mankato in the NW¼ sec. 31, T. 109N.; R. 25W. This is a sedge-grass bog of the filled-lake type, and is covered by vegetation consisting chiefly of sedges and grasses.

The bog contains an area of about 256 acres and the peat has an average depth of about 10 feet and a maximum depth of more than 15 feet. The peat is dark brown, soft, well decomposed, and rather plastic. The material in the upper 2 feet is fibrous. The peat consists chiefly of sedges and grasses with a few remains of bulrushes and cattails.

A sample was taken from top to bottom of the deposit in a test hole located at the roadside half way across the bog, and near the shore of Eagle Lake.

Analysis 49 (page 77), shows the composition of the peat. It has a high thermal value, and the amount of ash is not excessive. The high nitrogen content, 2.83 per cent, suggests that it may be valuable as a fertilizer.

Locality 58.—Bog 3½ miles northeast of Mankato; NE¼ sec. 27, T. 109N., R. 26W. This is a small bog comprising an area of about 25 acres. The average thickness of the peat is about 4 feet, with a maximum of 8 feet. The peat is earthy and too high in ash to be of any value for peat fuel. No sample was taken for analysis.

Locality 59.—Bog 6 miles northeast of Mankato on the east shore of Lake Wita. This is a small sedge-grass meadow containing an area of about 50 acres. The average thickness of the peat is about 7 feet, and the maximum is 13½ feet, as indicated by test holes. The bog contains well decomposed, firm, brown peat, made up chiefly of sedge and grass remains. Samples were taken from the top 32 inches of the deposit from each of ten test holes, and all mixed in a sample sack. The test holes were spaced every 150 feet along an east and west line across the center of the bog.

Analysis 52 (page 77) which represents this sample, indicates that the material is a fuel peat of fair quality, with a high nitrogen and low sulphur content.

Locality 60.—Bog 5 miles northeast of Mankato on the west shore of Lake Wita. The area is a small sedge-grass meadow containing about 75 acres of peat, which has an average thickness of 5 feet. The maximum thickness indicated by test holes is 9 feet. The peat is of a brown color, firm and fibrous, and consists chiefly of sedge and grass remains. Samples were taken from the top 32 inches of the deposit from each of ten holes, spaced every 150 feet along a line across the bog from north to south, through the center. The samples were all mixed together.

Analysis 53 (page 77) which represents this sample shows that the peat contains too much ash to be of value for fuel.

Locality 61.—Bog 3½ miles northeast of Mankato; SE¼ sec. 22, T. 109N., R. 26W. This is a small open sedge-grass meadow, which covers an area of about 40 acres. The peat is from 5 to 9 feet thick with an average of about 6 feet. It is composed of sedge and grass remains mixed with a large amount of mineral soil, and approaches the composition of muck. Samples were taken of the top 32 inches of peat from each of 10 holes spaced every 150 feet along a line across the middle of the bog.

Analysis 54 (page 77) indicates that the material is not suited to the manufacture of peat fuel.

Locality 62.—Bog 3½ miles northeast of Mankato; SW¼ sec. 22, and SE¼ sec. 21, T. 109N.; R. 26W. This bog is of the sedge-grass meadow type, and occupies an area of about 50 acres. The average thickness of the peat is 6 feet, and a maximum thickness of 11 feet was indicated by test holes. The deposit consists of well decomposed, brown peat, formed chiefly from sedges and grasses. Samples were taken from the top 32 inches of the deposit from each of 10 test holes, and all mixed together in a sample sack. The holes were spaced every 75 feet along a line across widest portion of the bog, from east to west.

Analysis 55 (page 77) represents this sample. There was too much ash present for a good fuel peat, but the high content of nitrogen might be utilized.

Locality 63.—Bog 3 miles northeast of Mankato; SE¼ sec. 28; NE¼ sec. 33; and NW¼ sec. 34; T. 109N.; R. 26W. This is another sedge-grass meadow containing peat made up of the remains of these plants. The area comprises about 160 acres of peat, of an average thickness of 7 feet, and a maximum of 11 feet as indicated by test holes. The peat is firm, well decomposed, and of a brown color. Samples were taken from the top 32 inches from each of 10 holes, and mixed together in a sack. The holes were spaced every 150 feet along a north and south line, and an east and west line through the center of the bog.

Analysis 56 (page 77) represents this sample and indicates an ash content somewhat higher than that which a good fuel peat should have.

Locality 64.—Bog 4 miles northeast of Mankato; NW¼ sec. 26; T. 109N.; R. 26W. This is a small sedge-grass meadow of about 40 acres. The peat has an average depth of about 5 feet, and the maximum depth indicated by test holes is 7½ feet. The peat is firm, and of a dark brown color, and consists chiefly of sedge and grass remains. Ten test holes were sunk at 75-foot intervals along an east and west line across the widest part of the bog, and peat samples were taken from the top 32 inches from each of the 10 holes, and mixed in a sack.

Analysis 57 (page 77) shows that the peat is of a poor quality for fuel.

Locality 65.—This sample was taken from the same bog as that described under Locality 101 (page 77). The composition and character of the peat is identical with that described under Locality 101, and therefore no additional description need be given here.

Locality 66.—Sedge-grass meadow about 3 miles northeast of Mankato. The area of the bog is about 64 acres, and the peat has an average depth of about 7 feet with a maximum of 13 feet as indicated by test holes. The peat is dark brown to black, firm and somewhat earthy. Ten test holes were sunk at 150-foot intervals along a north-south line across the bog parallel to the longest axis. Samples were taken from the top 32 inches from each of the 10 holes and mixed in a sample sack.

Analysis 58 (page 77) shows that the ash content is too high for peat fuel. The very high nitrogen content, 3.01 per cent, is noteworthy.

Locality 67.—Bog about 6 miles northeast of Mankato on the northeast shore of Eagle Lake. This sample comes from the same bog as Locality 101. This is a meadow extending back from the lake shore and is covered with sedges and grasses, with a few swamp-willows. The area is only about 25 acres. The peat is unusually thick, the average depth being about 10 feet with a maximum of more than 15 feet. The peat is fibrous on top and decomposed below, and of a brown color. It is composed chiefly of sedge and grass remains. Ten test holes were sunk, spaced at 150-foot intervals, along an east-west line across the middle of the bog, and samples were taken from the top 32 inches from each of the 10 holes and mixed in a sack.

Analysis 59 (page 77) shows this peat to be of fair quality for fuel. The nitrogen content is unusually high (2.92 per cent).

Locality 69.—Bog 8 miles northeast of Mapleton; W½ of sec. 15, T. 106N., R. 25W. This is a sedge-grass meadow comprising an area of about 134 acres, containing black and earthy peat of an average depth of 5 feet. The maximum depth indicated by sampling is 9 feet. No samples were taken for analysis since the ash content would be much too high for peat fuel.

Locality 70.—Sedge-grass meadow 8 miles east of Mapleton. The area of this bog is about 224 acres, and the average depth of peat is about 5 feet with a maximum depth of 8½ feet as indicated by test holes. The peat is brown and fibrous and is made up mostly of sedges and grasses. Test holes were located every 150 feet along a north-south line through the center of the bog, and samples were taken from the top 32 inches from each of the 10 holes, and all mixed in a sample sack.

Analysis 60 (page 77) shows the ash content to be much too high for peat fuel.

Locality 71.—Bog 5½ miles northeast of Mankato; NE¼ sec. 23.; T. 109W.; R. 26W. This is a small meadow of about 25 acres containing brown, fibrous, earthy peat, or muck, of an average depth of 4 feet. No samples were taken for analysis since the large amount of mineral soil in the peat renders it unfit for fuel.

Locality 73.—This is a small meadow of about 10 acres located in the SE¼ sec. 22; T. 109N.; R. 26W. The peat is earthy and similar to that described under Locality 71. The depth of the peat is only 6 inches to 1 foot. No samples were taken for analysis.

Locality 74.—This is a small meadow, located in the NE¼ sec. 28; T. 109N.; R. 26W., and is similar to that just described under Locality 73. The area is only about 12 acres, and the average thickness of the peat is less than 1 foot. No samples were taken for analysis.

Locality 75.—Bog in E½ sec. 33; T. 106N.; R. 25W. and E½ sec. 4; T. 105N.; R. 25W. The peat in this bog is of an earthy nature and approaches the composition of muck. The average thickness is about 2 feet over an area of about 350 acres. No samples were taken for analysis. This bog, if properly drained, could be used for farming, since the peat is so shallow it could be plowed into the soil.

Locality 76.—Meadow bog in E½ sec. 33; and SW¼ sec. 27; T. 106N.; R. 26W. The bog contains earthy peat or muck, and comprises an area of about 198 acres. The average depth of the muck is only 2 feet. No samples were taken for analysis.

Locality 77.—NE¼ sec. 5; and NW¼ sec. 4; T. 105N.; R. 26W. This is a grass-sedge meadow similar to that described under Locality 76, and contains an area of about 147 acres. The average depth of the muck is only 2 feet. The amount of mineral soil in the peat, or muck, renders it unfit for fuel. No samples were taken for analysis.

Locality 78.—Sedge-grass meadow similar to that just described under Locality 77. This bog is located in the NE¼ sec. 9; T. 105N.;

R. 25W. The area is about 115 acres, and the average depth of the muck is 3 feet. No samples were taken for analysis.

Locality 79.—Bog about 2 miles south of Madison Lake post-office in the NW¼ sec. 9; T. 108N.; R. 25W. This is a sedge-grass meadow with an area of about 30 acres. The peat, which consists of brown, well decomposed sedge and grass remains, has an average depth of about 5 feet. Ten test holes were put down at 150-foot intervals along a line through the center of the bog, and samples were taken from the top 32 inches from each of the 10 holes and mixed.

Analysis 61 (page 77) which represents this sample, shows it to be too high in ash and too low in fixed carbon for fuel.

Locality 80.—Sedge-grass meadow about 3 miles south of Madison Lake. This bog comprises an area of about 134 acres, and contains brown, well decomposed peat, having an average depth of about 10 feet and a maximum depth of 15 feet as indicated by test holes. Ten of these holes were sunk, located at 150-foot intervals along a line through the center of the bog. Samples were taken only from upper 32 inches of the deposit, from each of the ten holes, and mixed.

Analysis 62 (page 77) shows this peat to possess a rather high thermal value, but the ash content is higher than it should be for first-class fuel peat. The nitrogen content (3.10 per cent) is exceptionally high, and the peat may be of value as a fertilizer.

Locality 81.—Bog 11 miles east of Mankato, in SE¼ sec. 14; E½ sec. 23; and NE¼ sec. 26; T. 108N.; R. 25W. This is a sedge-grass meadow comprising an area of 410 acres. The peat, which has an average thickness of 7 feet and a maximum thickness of 15 feet, consists of brown, well decomposed material, made up chiefly of sedge and grass remains. Ten test holes were sunk at 150-foot intervals along a line through the center of the bog, and samples were taken of the upper 32 inches of the peat, from each of the 10 holes, and mixed. Analysis 63 (page 77) represents this sample. The high nitrogen content (3.13 per cent) is the most noteworthy feature. The ash content is higher than the average for Minnesota peat.

Locality 82.—Sedge-grass meadow about 10 miles east of Mankato; W½ sec. 14; T. 108N.; R. 25W. The area of this bog is about 64 acres, and the average depth of the peat is approximately 10 feet. The maximum depth as indicated by test holes is 15 feet. The peat is well decomposed, and is made up chiefly of sedge and grass remains. Test holes were put down at 150-foot intervals along a line through the center of the bog, and samples were taken from the upper 32 inches of the peat from each of 10 test holes, and mixed. Analysis 64 (page 77) represents this sample, and shows the peat to contain such a high ash content as to render it undesirable for fuel.

LAKE CRYSTAL

Locality 56.—Bog about 10 miles southwest of Lake Crystal, in NW¼ sec. 9; T. 106N.; R. 29W. This is an open sedge-grass meadow, covering an area of about 75 acres. The average thickness of the peat is about 5 feet but a maximum of 10 feet was indicated by test holes. The peat is well decomposed, firm material, of a brown color, and consists mostly of grass and sedge remains.

Samples were taken of the upper 32 inches of the peat from each of 10 holes spaced every 150 feet along an east-west line across the bog, and a short distance south of the center of the bog. Analysis 50 (page 77) represents the average of these samples, and shows the fixed carbon to be very low, and the ash content very high. The material more nearly approaches muck than peat and is of no value for fuel.

GOOD THUNDER

Locality 57.—Bog about 7 miles southwest of Good Thunder and 1 mile northwest of Jackson Lake. This is an open sedge-grass meadow comprising an area of about 50 acres. The average depth of the peat as indicated by test holes is about 5½ feet. The maximum depth obtained was 9 feet. Well decomposed, brown peat, made up mostly of grasses and sedges, fills this deposit. Samples were collected from the top 32 inches of the deposit from each of 10 holes and mixed in a sample sack. These test holes were spaced every 250 feet along a north-south line through the center of the bog.

Analysis 50 (page 77) shows the ash to be too high for a good fuel peat. The high nitrogen content is noteworthy.

BROWN COUNTY

Brown County is situated in the central part of southern Minnesota, about 75 miles southwest of Minneapolis and St. Paul. It lies within the basin of the Minnesota River. The area of the county is 616.75 square miles, or 394,720.82 acres. There are no peat deposits which would be of commercial value for peat fuel in competition with those of Blue Earth County, which adjoins Brown County on the east. Most of the marshy areas in Brown County contain shallow deposits of muck, and could be cultivated if they were properly drained.

CARLTON COUNTY

According to the report of the Minnesota State Drainage Commission,[71] there were originally in Carlton County 70,000 acres of wet lands. Not more than half of this area, or 35,000 acres, contains peat. About 25,000 acres of this land are covered by peat of considerable thickness,

[71] Minnesota State Drainage Commission, *Annual Report for 1913* p. 138.

a large part of which could be utilized for the manufacture of fuel. The remainder of the wet land in the county is covered by black muck, or shallow peat in which there is a large content of mineral soil.

Most of the peat swamps occur in the northwest quarter of the county, particularly in the region around Corona and Sawyer, on the Northern Pacific railroad. These swamps are typical muskegs, and the peat in some of them is 35 feet deep. (See Corona Bog, Locality 13.) There is also some peat in the southwestern quarter of Carlton County, but it is shallower than that to the north, and occurs in smaller deposits. There are also small peat bogs around Carlton on the Fond du Lac Indian Reservation, and some of these are shown on the soil map of the Carlton Sheet, published by the Bureau of Soils, U. S. Department of Agriculture.

The following descriptions of the bogs tested may be taken as typical of the larger muskegs in this county.

CORONA

Locality 13.—Large bog at Corona station on the Northern Pacific railroad. This is a typical muskeg, and the vegetation consists of tamarack, spruce, heaths, blueberry, cranberry, sphagnum, cotton grass, sedges, and other plants. The peat is underlain by sand, in the deeper parts of the bog. The deposit is a peat-filled lake, which has been built up at least 10 feet above the old water level. The peat has been deposited over the surface of the land for several miles on all sides of the original lake site. Soundings show that the deepest part of the bog is still a floating mat, which is about 30 to 35 feet thick, beneath which there is water.

The area of this bog comprises many square miles, but the deepest and most accessible peat covers an area of about 2½ square miles at Corona. The thickness of the peat varies from 25 to 35 feet over a large area around Corona station. The average thickness is between 10 and 20 feet, probably about 15 feet.

In character the peat is brown and fibrous, but almost structureless, decomposed material. The upper 10 feet is fibrous and mossy, and composed chiefly of sphagnum, whereas the lower portion is of a lighter color, more plastic, and composed largely of remains of sedges and pond plants. Many old tamarack stumps and roots are imbedded in the upper portion of the deposit.

The location of the test holes and the distribution and thickness of the peat is shown in Figure 5. Samples were collected every 2 feet in depth from the top to the bottom of each of holes 1 to 19 inclusive (except 18A), and all mixed in a sample sack in order to obtain an average. The results of sampling were as follows:

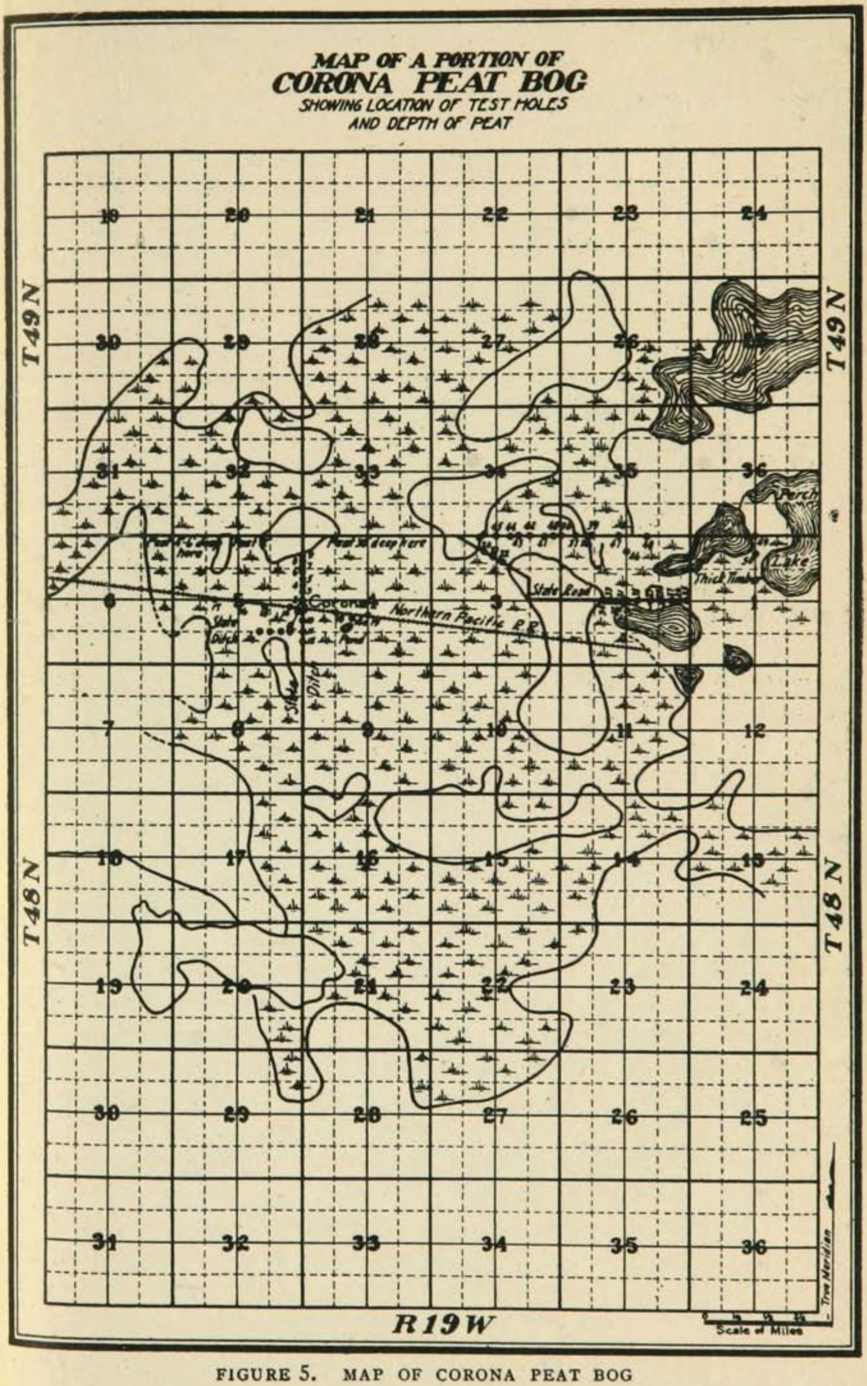

FIGURE 5. MAP OF CORONA PEAT BOG

Description of Test Holes

(Numbers correspond to those on map)

No. of hole	Thickness of peat in feet	Remarks
1.	34+	Rods not long enough to reach bottom of peat
2.	22+	Rods not long enough to reach bottom of peat
3.	18+	Rods not long enough to reach bottom of peat
4.	18+	Rods not long enough to reach bottom of peat
5.	18+	Rods not long enough to reach bottom of peat
6.	18+	Rods not long enough to reach bottom of peat
7.	17½	Sand bottom. Peat firm, top to bottom
8.	13	Sand bottom. Peat firm, top to bottom
9.	4	Near edge of an island in the bog
10.	18+	Rods not long enough to reach bottom. Excellent peat
11.	18+	Rods not long enough to reach bottom. Excellent peat
12.	18+	Rods not long enough to reach bottom. Excellent peat
13.	18+	Rods not long enough to reach bottom. Excellent peat
14.	18+	Rods not long enough to reach bottom. Excellent peat
15.	18+	Rods not long enough to reach bottom. Excellent peat
16.	14	Gray sand bottom
17.	9	Sand bottom. Near edge of bog. Much grass on surface
18.	18+	Rods not long enough to reach bottom
18-A.	50+(?)	Lower 20 feet was water. Reported by N. P. R. R. Co. Near lake in center of bog
19.	9	Blue clay bottom. Approaching an island

Analysis 65 (page 77) which represents this bog, shows the peat to be of excellent quality for fuel. The thermal value is high and the ash content is low. This is one of the deepest and largest open heath bogs in Minnesota. The Northern Pacific railroad crosses the open portion of the bog, and there is a station and siding at Corona, located on the bog. The area has already been partially drained, and lateral ditches could easily be run to the main ditch which is already completed. The bog offers one of the best locations in the state for the establishment of a peat fuel plant.

SAWYER

Locality 214.—Bog 1½ miles east of Sawyer station along the Northern Pacific railroad. This is a quaking heath bog and represents a peat-filled lake. Vegetational zones are well marked around this bog, which is covered with water in the center. The plants comprising the various vegetational zones consist of wild rice and pondweeds in the center; next, toward the shore, is a zone of sedges with a few cattails; beyond this is a typical heath bog which contains a few dead tamarack trees.

The area of the bog is about 320 acres, and the average depth of the peat is more than 18 feet. The maximum depth could not be obtained because the sampling instrument was not long enough to reach bottom. In character, the peat is decomposed and structureless, and is made up largely of the remains of pondweeds and sedges.

The location of the test holes is as follows:

Hole 1—300 feet north of railroad, 300 feet from margin of bog; thickness 6 feet.
Hole 2—300 feet north of No. 1; thickness 12 feet.

Hole 3—300 feet north of No. 2; thickness 20 feet+ (could not reach bottom).

It was impossible to penetrate further into the swamp because of the soft, boggy character of the surface.

Analysis 66 (page 77) represents this sample.

Locality 215.—Muskeg swamp 2 miles west of Sawyer station along Northern Pacific railroad tracks. SW¼ sec. 6; T. 48N.; R. 18W. The vegetation of this bog consists of tamarack and spruce trees (now dead), heaths, sphagnum, and cotton-grass. The peat is underlain by sand. The deposit represents a filled lake which has been further built up by subsequent accumulation of peat.

The area comprises about 100 acres, and the average thickness of the peat, as indicated by test holes, is approximately 9 feet. The peat is well decomposed, red to dark brown in color, somewhat fibrous in the upper portion, and greenish near the bottom. It is made up chiefly of sphagnum and heath remains with sedges and reed-grass recognizable in places.

The location of the test holes is as follows:

Hole 1—200 feet north of track, near edge of bog; thickness 10 feet.
Hole 2—200 feet west of No. 1 parallel to track; thickness 9 feet.
Hole 3—200 feet west of No. 2 parallel to track; thickness 9 feet.

Analysis 67 (page 77) represents this peat.

Locality 216.—Muskeg 1½ miles west of Sawyer station, with vegetation consisting chiefly of tamarack and spruce trees, heath shrubs, sphagnum and polytrichiem moss, and sedges. The peat is underlain by coarse sand, and the deposit represents a combination of filled pond and built-up deposit.

The bog contains an area of about 360 acres. The average thickness of the peat is approximately 12 feet as shown by test holes. The upper 2 feet of the deposit consists of a red brown, woody peat. Below this there is 6 feet of light brown, fibrous to decomposed, plastic peat. At 12 feet a layer of moss occurs which is underlain by 1 to 2 feet of greenish, impure pond peat. The material is made up chiefly of reeds, sedges, and wood near the top. The middle portion consists chiefly of the remains of sedges with some broad blades of reed-grass or cattails. The bottom layer contains remains of pondweeds.

Test holes were located as follows:

Hole 1—100 feet south of railroad; 500 feet south of margin of bog; thickness 13 feet.
Hole 2—200 feet south of No. 1, at east edge of lake; thickness 12 feet.
Hole 3—200 feet south of No. 2; thickness 10 feet.
Hole 4—200 feet south of No. 3; thickness 10 feet.

Analysis 68 (page 77) represents this sample. The deposit is well situated for development, and the peat is of excellent quality. The

Northern Pacific railroad crosses the deposit. Very little clearing would be necessary as the trees are small and scattered.

CARVER COUNTY

The northeast portion of Carver County, which lies just south of Lake Minnetonka, has a rather rough morainic topography, but the remainder of the county consists of a broad, nearly flat, outwash plain. There are a considerable number of small peat bogs of minor importance in the morainic belt of the northeast corner. These belong to the group of small bogs which occur in large numbers throughout the Lake Minnetonka region. There are few peat deposits in the remainder of the county except along the flats of the Minnesota River valley, on the extreme eastern border. At some localities along the river, the flood plain of the stream is covered with a peaty muck, but examination of the material shows it to be too high in ash to be of any value for fuel. The land is subject to overflow almost every year and hence is of little value for farming. The Report of the State Drainage Commission, 1913, gives the original area of wet land in the county as only 2,200 acres. Most of this is now drained and under cultivation.

CASS COUNTY

Cass County contains numerous peat deposits, the largest of which occur on the glacial plain east of Leech Lake in the northeast part of the county. Small bogs are distributed throughout the county, many of which are around the shores of the numerous lakes which dot the surface. Most of the big peat bogs of the northeast quarter of the county are open sedge or grass marshes. The largest of these are found around the north and east shores of Leech Lake and eastward. The small bogs of the central and southern parts of the county are of two types, muskegs and meadows. Some of these represent peat-filled lakes, while others are built-up deposits extending back from the shores of existing lakes.

The topography of Cass County is especially favorable to the accumulation of peat deposits. It consists of alternating moraines and outwash plains, with many undrained basins and kettle holes in the drift. Most of the existing lakes, of which there are hundreds, as well as the peat bogs, occupy basins or depressions of this type.

The total area of wet land in the county is about 85,000 acres. Probably not more than 75,000 acres are covered with peat, and much of this land contains only shallow peat, one or two feet deep. Some of the largest swamps and marshes, however, are covered with peat to a depth of 8 or 10 feet, which makes the average depth of all the peat lands in the county 4 or 5 feet.

Descriptions of some of the typical deposits are given below.

WILKINSON

Locality 125.—Bog 1½ miles south of Wilkinson along the Great Northern railroad tracks. The bog which was originally a muskeg, has been drained, and the typical vegetation has been largely destroyed. The most abundant plants now growing on the bog are sedges, grasses, and cattails. Many dead tamarack stumps occur buried in the peat, and the surface of the bog was covered with water 2 feet deep at the time of investigation.

This is a long narrow marsh along Steamboat River covering an area of several square miles. The average thickness of the peat is about 8 feet and consists of brown to black, soft, rather fluid material, in the upper 6 feet, below which there is 2 feet of firm, stratified peat containing sedge remains, and below that 1 foot of soft, decomposed peat. A burned twig or piece of charred wood was found at the bottom, 9 feet below the surface.

The test holes were located as follows:

Hole 1—100 feet north of edge of bog along track. Black muck: 2 feet.
Hole 2—500 feet north of No. 1 along track; thickness 2 feet. Silty black peat; coarse sand bottom.
Hole 3—500 feet north of No. 2 along track; thickness 9 feet. Dark brown, decomposed peat.
Hole 4—500 feet north of No. 3 along track; thickness 9 feet. Top peat is fluid. Middle of bed is firm.
Hole 5—500 feet north of No. 4, mile post 129; thickness 7 feet. Top peat is fluid. Middle of bed is firm.
Hole 6—1,000 feet north of No. 5; thickness 7 feet. Water 3 feet deep on surface.
Hole 7—500 feet north of No. 6. 300 feet from north edge of bog. Water on surface too deep to get sample.

No samples for analysis were taken at this locality because the bog is subject to floods from high waters in Leech Lake, and the land could not be used for any purpose with safety until these floods are controlled, which would involve a large expenditure.

BENA

Locality 149.—Quaking bog 3 miles east of Bena station on Great Northern railroad. The vegetation consists of small tamarack trees, sedges, grasses, and a little sphagnum. The peat is underlain by coarse sand. The area includes about 160 acres. The average thickness of the peat is 7 feet. The peat, which is light brown to dark brown and well decomposed, is underlain by muck.

Test holes were located as follows:

Hole 1—Mile post 43. 200 feet from edge of bog; thickness 4 feet, undecomposed peat in upper 2 feet.
Hole 2—800 feet west of No. 1. Center of bog; thickness 8 feet.
Hole 3—800 feet west of No. 2. 200 feet from edge of bog; thickness 6 feet.

No analysis was made of the sample from this deposit. The bog could not be used as a source of peat fuel, because the surface is covered with water 2 feet deep. It would be very difficult to drain this area, and the expense of such drainage would be prohibitive in an attempt to utilize the peat for fuel.

FEDERAL DAM

Locality 150.—Open marsh ½ mile northwest of Federal Dam station on the Soo railroad. This is an arm of a big marsh extending for miles along the northeast shore of Leech Lake. The vegetation consists chiefly of sedges. Bulrushes grow along Leech Lake River. Near the edge of the bog there is a heath zone with sphagnum, and at the extreme edge there is a zone of tamaracks. The peat is underlain by sand. The deposit occupies the drainage channel of Leech Lake River. The average thickness of the peat is about 4 feet as indicated by test holes, located as follows:

Hole 1—200 feet from southeast margin along the railroad. No sample taken. Peat is gritty and black.
Hole 2—¼ mile northwest of No. 1 along railroad; thickness 4 feet.
Hole 3—¼ mile northwest of No. 2; mile post 333; thickness 5 feet.
Hole 4—200 feet northwest of No. 3; 200 feet from edge; thickness 4 feet.

Analysis 71 (page 77) shows the composition of this peat. The marsh was at one time used as a source of supply of sedges and grasses for the manufacture of "grass" carpets and rugs. The area is subject to floods at periods of high water in Leech Lake.

Locality 151.—This is a portion of the same big Leech Lake marsh just referred to under Locality 150. The portion of the marsh here referred to lies 4 miles northwest of Federal Dam station along the Soo railroad. The average thickness of the peat here is approximately 8 feet. A maximum thickness of 10 feet was indicated by test holes, located as follows:

Hole 1—At intersection of the railroad and ditch in the middle of the bog; thickness 10 feet. Clean peat.
Hole 2—300 feet west of railroad along ditch; thickness 4 feet. Almost at edge of bog.
Hole 3—300 feet east of railroad along ditch; thickness 8 feet.

The peat is brown, partly decomposed, and stratified. The upper 3 feet are made up chiefly of sphagnum and polytrichiem moss, while below this depth it is composed mostly of sedge and bulrush remains. The peat is underlain by several inches of sand below which clay occurs.

Analysis 72 (page 77) represents this sample.

BACKUS

Locality 166.—Bog 5½ miles north of Backus on the Minnesota and International railroad, near Island Lake. This is a tamarack-spruce-cedar swamp. A dense growth of these trees covers the bog. The surface of the bog between the trees is covered with sedges, heaths, moss, and a few shrubs. The peat is underlain by soft marl, full of organic matter and plant remains. The bog represents a peat-filled lake, and the surface has been built up several feet above the old lake level.

The swamp, of which this locality represents an arm, covers an area of about 2 square miles. The average thickness of the deposit where sampled is about 10 feet, but a maximum thickness of more than 20 feet was shown by test holes. The upper 6 feet of peat is firm and somewhat fibrous; below this, it is dark brown, and rather fluid to plastic. The peat is composed chiefly of a fine hair-like grass, or sedge. A little moss was noted at a depth of 3 feet. The location of the test holes is as follows:

Hole 1—Mile post 47; 1,000 feet from north edge; thickness 12 feet. Soft, light brown peat. Gray near bottom.
Hole 2—500 feet south of No. 1; thickness 20+ feet. Many roots.
Hole 3—500 feet south of No. 2; thickness 10 feet. Peat is underlain by muck.
Hole 4—1,000 feet south of No. 3, 600 feet from south margin; thickness 8 feet. Much moss on the surface. This peat was so fluid it could not be retained in the sampler cylinder. The samples represent only the upper 6 or 7 feet.

Analysis 73 (page 77) represents this sample. The bog is very firm on the surface, but the peat is almost as fluid as water below a depth of 7 feet. The sampling rods had to be held to prevent them dropping out of sight in the bog from their own weight. The deposit is apparently a floating peat mat over a lake which is not yet completely filled.

Locality 167.—Quaking bog 2¼ miles north of Backus station, along the Minnesota and International railroad, secs. 17 and 20, T. 139N.; R. 30W. This represents a filled portion of a lake on the shores of which the bog is now forming. The sedge mat is very thin near the lake and will not support the weight of a man. The vegetation consists chiefly of sedges and grasses, with patches of sphagnum associated with heath shrubs (*Andromeda*). The area comprises about 160 acres, over which the peat averages 5 feet thick. The maximum thickness indicated by test holes is 7 feet. The peat is brown, spongy or fibrous on top, and well decomposed below. It is made up chiefly of sedges with remains of bulrushes and cattails. Test holes were located as follows:

Hole 1—500 feet east of railroad track from mile post 45; thickness 4 feet.
Hole 2—500 feet east of No. 1; thickness 7 feet.
Hole 3—500 feet east of No. 2 (300 feet from east margin of bog); thickness 5 feet.

Analysis 74 (page 77) represents this bog. It would be difficult to drain the bog as it lies in a deep depression among hills of morainic debris, and has no outlet.

CHIPPEWA COUNTY

There is no peat in Chippewa County other than small quantities of peaty sod, or muck, in a few localities. The only swamp of importance in the county lies in the extreme southeast corner in secs. 32 and 33; T. 117N.; R. 37W.; and extends south into Renville County.

CHISAGO COUNTY

Small quantities of peat of commercial value occur in Chisago County, but none of these are of sufficient size to warrant attention at this time, in view of the much larger and more accessible deposits in Anoka County, which borders this county on the southwest. There are a number of very small tamarack swamps in Chisago County, all of which contain peat, but few of these are more than a few acres in area. All of the peat land in the county can be used for agricultural purposes when it is drained, and most of the peat is so shallow that deep plowing will reach the mineral subsoil below.

CLAY COUNTY

Clay County lies entirely within the Red River Valley. There is no peat in the county.

CLEARWATER COUNTY

Most of the peat swamps of Clearwater County occur in the 6 townships lying west of Red Lake, in the extreme northern portion of the county. This is shown on Plate I. Practically all of this land, as shown by the map, lies within the limits of glacial Lake Agassiz, which accounts for the swampy character of the surface. This locality, and the region immediately east of Red Lake, constitutes one of the most striking examples to be found anywhere in the state, of the influence of the topography of the bed of glacial Lake Agassiz on the development of peat bogs. In both of these localities the southern limits of the old lake bed also form the south edges of the peat deposits.

In addition to the large swamp referred to above, which is a continuation of the great Beltrami County swamp, there are hundreds of smaller peat bogs and swamps scattered over the central and southern parts of the county. Some of these attain considerable size. There are some especially extensive ones around Bagley and Shevlin, in the central part of the county, and around Rice Lake and Upper Rice Lake, in the southern part.

The total area of Clearwater County is 1,019 square miles, of which at least 200 square miles, or 19.6 per cent of the area is covered with peat. The depth of this peat is, in general, shallower than that to the east, in Beltrami County, but on the other hand, it is deeper than the Marshall County peat deposits, which lie to the west. The average depth in Clearwater County is about 5 feet. There are, however, some deep bogs of the filled-lake type scattered throughout the central and southern parts. The portion of the county to the south of the limits of glacial Lake Agassiz contains extensive moraines and till plains. These are dotted with marshy or swampy areas, all of which are covered with peat. In the morainic regions the basins are deeper and the peat bogs contain thicker deposits. On the till plains, there are numerous shallow, swampy depressions, which have become the sites of peat accumulation.

There are two main types of peat bogs in the county; (1) tamarack-spruce swamp; and (2) open sedge marshes. According to the Engineers' Report[72] on the Topographical and Drainage Survey of Minnesota from 60 to 70 per cent of the swamp lands of Clearwater County are covered with a growth of timber ranging from small one-inch tamaracks, to swamps heavily timbered with tamarack, spruce, and cedar. The remaining 30 or 40 per cent of the wet land consists of open marshes or "hay meadows." These open marshes and meadows all contain peat ranging in depth from 1 to 10 feet. The quality of the peat is the same as that in Beltrami and Marshall counties. In short, the Clearwater deposits form a part of the great Lake Agassiz peat swamp, which has been referred to often in the preceding pages.

COOK COUNTY

Cook County lies in the extreme northeast corner of Minnesota, and its southern boundary forms part of the north shore of Lake Superior. There are comparatively few peat swamps in Cook County. Most of the northern part, and a wide belt in the southern part parallel to the Lake shore is free from glacial drift and most of the rock outcrops in Minnesota occur in these regions. The topography is rougher than in other parts of the state, especially in northern Cook County, where it consists of alternating parallel rock ridges and rock valleys, all having a general east-west trend. In eastern Cook County, in the row of townships about midway between the north and south boundaries of the county, there are numerous muskeg swamps, similar in nature, and containing the same type of peat as the muskegs of St. Louis and the other counties to the west. The largest muskegs are in T. 63N.; R. 3E., and T. 63N.; R. 4E., but numerous small swamps are found in T. 63N.; R. 2E., and T. 62N. and R. 1E.

Cook County is the most inaccessible in the state, and the greater portion of its area is still a wilderness. Because of the inaccessibility of the region and the lack of transportation facilities, it was not considered worth the expense involved to do any detailed sampling of the

[72] George A. Ralph, *op. cit.*

peat deposits in this county. There are larger, deeper, and better peat bogs, containing an ample supply of peat fuel, which occur in the other counties of northern Minnesota, where transportation facilities are adequate. From an agricultural point of view, the peat in many of the Cook County bogs is the only soil there is. Below this peat occurs the bare glaciated rock surface. To remove the peat would render the land unproductive.

COTTONWOOD COUNTY

Most of Cottonwood County is nearly level and a large part of it is poorly drained. There are numerous depressions in the low, flatly rolling surface, many of which contain small lakes, especially in the southern half of the county. These lakes however, do not contain much peat, and most of them have sandy or gravelly bottoms. The peat forming plants have not invaded the lakes to any great extent, partly because of the sandy nature of the bottom, and partly because of the depth of the water, which, in many, is too great for such vegetation to thrive.

There are a large number of swampy areas in the southern part of Cottonwood County, but none of them contain peat in sufficient quantity to be of commercial value for peat fuel. Some of the peat might be utilized locally for packing or peat litter, but none of the deposits are over 2 or 3 feet thick, while the majority are less than 1 foot thick. Most of the deposits lie in Mountain Lake, Lakeside, Carson, Midway, Dale, Amo, and Rose Hill townships. The marshes are of three types; (1) drained lake beds, which usually have only 6 to 12 inches of peat underlain by sandy or gravelly clay; (2) low undrained depressions in the prairie, which are always wet but contain standing water only after rains; and (3) marshes along the Des Moines River, above and below Windom. The largest peat deposit lies in the bed of Mountain Lake, which has recently been drained. This was carefully examined and sampled, and may be taken as typical of the peat of this region. It was found too shallow to be of value. A description of the deposit is given below.

Warren Upham,[73] in his report on the geology of Cottonwood County, says that in former years the peat bogs here were quite extensively relied on for local fuel. This was true of the early days when settlers were few, coal was not to be had, and wood was scarce. But the fuel derived from the peat of this region must have been poor, and its use was discontinued with the building of the railroads and transportation of good fuel. The following localities given by Upham now contain peat from 6 inches to 12 inches thick; and before these areas were

[73] Warren Upham, Geological and Natural History Survey of Minnesota 1:514, 515. 1872-1882.

drained the peat was probably approximately twice as thick. The partial or complete drainage of the land will readily account for the apparent discrepancies in the thickness of the peat as given by Upham and Winchell and as now existing. It was from these localities that the peat used in the early days was taken.

Mountain Lake T.; peat 10 to 24 inches thick.
Lakeside T.; secs. 20, 29, and 31; peat 12 inches thick.
Great Bend T.; sec. 28; shallow turfy peat.
Amo T.; sec. 13; peat 2 to 3 feet thick.
Southbrook T.; "Sidehill peat" formerly was present.
Dale T.; secs. 22 and 24.

MOUNTAIN LAKE

Locality 111.—Marsh 2 miles southeast of Mountain Lake station on the Chicago, St. Paul, Minneapolis, and Omaha railroad in secs. 1, 2, 10, and 11, T. 105N.; R. 34W. This area which covers about 2 square miles, represents the bed of a recently drained lake. The lake has been drained only 3 or 4 years, and the heavy vegetation now growing on the marsh has not had sufficient time to form much peat. The lake bed consists of gravelly sand. The vegetation is chiefly sedges, bulrushes, cattails and wild barley. About 1 to 2 feet of peat has formed since the bog was drained. The deepest peat lies at the south end of the marsh. Over most of the area the peat, which is brown, fibrous, undecomposed, and silty, is less than 2 feet thick. No test holes were necessary as the peat was exposed on the sides of drainage ditches across the bog, from which samples were collected. Analysis 75 (page 77) represents this bog. The marsh, when properly drained, will be of value for agricultural purposes. A large part of the area has been plowed and planted with potatoes. The remainder of the marsh is used for pasture.

CROW WING COUNTY

The land surface in Crow Wing County is of a more rolling nature than that of most of northern Minnesota, and many moraines occur here, with their characteristic irregular hills and intervening undrained basins or depressions. The northern half of the county is dotted with hundreds of lakes. The peat swamps of this region are small but numerous, and are scattered throughout almost every township in the county. The largest occur in townships 136, 137, and 138N.; R. 25W., in the northern part of the county, and T. 43 and 44N.; R. 26W., in the southern part.

There are 122,680 acres[74] of swamp land in Crow Wing County. Field studies made in preparation for the present report show that not

[74] George A. Ralph, Engineer's Report of the Minnesota State Drainage Commission. 1906.

more than one half of this area, or 61,340 acres, can be classified as peat land.

There are 2 main types of peat deposits in the county: (1) muskeg swamps, generally sparsely timbered with small tamarack and spruce; and (2) open marshes or meadows, generally covered with a heavy growth of marsh grasses and sedges. About 60 to 75 per cent of the total wet land area belongs to this latter type (open marsh), and the remaining 25 to 40 per cent consists of muskeg swamps. The depth of the peat is extremely variable, as would be expected in a region where the bogs are of such different types. The average depth of the peat is not more than 5 or 6 feet. At several localities in Crow Wing County, excellent marl beds were found, either beneath the waters of existing lakes, or underlying peat beds in filled lakes. One of the best of these marl deposits occurs near Pequot under Star Lake in the NE¼ sec. 25; T. 137N.; R. 28W. on the farm of Mr. Peterson. Another lies in NE¼ sec. 27 and NW¼ sec. 26; T. 137N.; R. 28W. on the north shore of Kimble Lake, 8 miles east of Pequot. A third lies in secs. 1 and 2; T. 136N.; R. 28W. along Pelican Creek; and a fourth in sec. 14; T. 45N.; R. 29W. on land belonging to Mr. Ray Cook.

Several of the typical peat deposits in the county were carefully studied and the bogs were sounded and sampled. The results are stated below.

STAR LAKE

Locality 42.—Bog around shores of Star Lake, sec. 25; T. 137N.; R. 28W. This is an open meadow which represents a filled arm of Star Lake. The vegetation consists of grasses, sedges, and sphagnum. The peat is underlain by at least 10 feet of pure marl.

The area of the bog is about 90 acres, and the average depth of the peat is approximately 5 feet. It is light brown, spongy to fibrous peat, composed chiefly of grass and sedge remains with mossy layers on top. A composite sample was collected along the drainage ditch which extends parallel to the long axis of the bog. Analysis 76 (page 77) represents this sample. The quantity of peat in this bog is perhaps too small to make it attractive as a location for a peat fuel plant, but the large deposit of excellent marl which underlies the peat has a commercial value, and will probably be utilized at some time in the future.

PELICAN CREEK

Locality 43.—Open meadow bog along Pelican Creek about ¾ mile north of Pelican Lake. The vegetation consists mostly of sedges, grasses, and moss. The deposit occupies an estuary between two lakes. The peat is underlain by at least 2 feet of marl which was formed by the filling in of the shallow estuary connecting the lakes. The peat has gradually built up the surface of the bog. The area of this deposit is about 250 acres, and the average thickness of the peat is approximately 5 feet. The peat is brown and fibrous in the upper half of the deposit and more decomposed in the lower portion. It consists chiefly of the remains of sedges, grasses, moss, and aquatic plants. Analysis 77 (page 77) represents this peat.

CROSBY

Locality 55.—This is a small muskeg, located near the Thompson mine at Crosby. It is covered with sphagnum, tamarack, and spruce, and the usual moss and heaths. The peat is underlain by glacial drift and iron ore. The area of the deposit is only about 30 acres. The peat which is about 6 feet thick, is of a brown color and considerably decomposed. The sample from which the analysis was made was collected by the Crosby Exploration Company. Analysis 78[75] (page 77) represents this sample. This deposit has been drained and most of the ground was excavated in stripping the iron ore-body.

LOERCH

Locality 165.—Marsh 1 mile east of Loerch station on the Northern Pacific railroad. The vegetation consists mostly of grasses, cattails, bulrushes, and sedges. The bog covers an irregular area several square miles in extent south and east of the railroad. The average thickness of the peat is only 3 feet, with a maximum thickness of 5 feet, as indicated by test holes. The character of the peat is fibrous, undecomposed, and somewhat fluid. It is made up of sedges, bulrushes, reeds, and grasses. Test holes were located as follows:

Hole 1—Near east margin; thickness 5 inches. Spongy fibre.
Hole 2—500 feet west of No. 1; thickness 3 feet. Grass, reeds and bulrushes.
Hole 3—¼ mile west of No. 2; thickness 3 feet.
Hole 4—500 feet south of No. 3; thickness 4 feet.
Hole 5—500 feet south of No. 4; thickness 4 feet.
Hole 6—500 feet south of No. 5; thickness 3 feet.
Hole 7—500 feet south of No. 6; thickness 2 feet.

Analysis 79 (page 77) represents this sample. The peat deposit is too shallow to be used for fuel. The land could be made to yield an excellent crop of wild hay if the marsh were properly drained.

DAKOTA COUNTY

The largest deposits of peat in Dakota County occur along the Minnesota River valley in the region between Savage and Mendota. There are scattered areas of meadow peat throughout the county, one of the largest of which occurs about one mile north of Farmington,

[75] Professor F. F. Grout of the University of Minnesota made the analysis.

west of the Chicago, Milwaukee, and St. Paul railroad. These meadow bogs, or marshes, are all shallow and do not contain peat deposits of sufficient thickness to be worked for machine peat fuel. For this reason no samples were taken from these meadows for fuel analysis. The large bogs along the Minnesota River were tested and the following description is typical of a number of peat bogs of this nature. The peat is too silty or sandy to make good fuel.

SAVAGE

Locality 253.—Sedge-grass marsh in Minnesota River bottom, 1 mile northeast of Savage along the Chicago, St. Paul, Minneapolis, and Omaha railroad. The peat is underlain by fine sand. The deposit is flooded at periods of high water and much silt is washed in and mixed with the peat.

The marsh is several square miles in extent and is covered by peat 2 to 10 feet thick. The average thickness is about 4 feet. The top of the deposit consists of brown, fibrous peat. Below this is red-brown, caked, decomposed peat to a depth of 8 feet in some places; this is underlain by soft, greenish peat. The composition of the peat varies greatly in different places on the bog. Remains of sedges, cattails, reed-grass, bulrushes, and moss predominate. Sand and silt become more noticeable in the lower layers of the deposit.

Test holes were located along a line through the center of the bog parallel to its long axis, as follows:

Hole 1—200 feet north of south margin; thickness 3 feet. Fibrous brown peat.
Hole 2—300 feet north of No. 1; no peat.
Hole 3—300 feet north of No. 2; thickness 4 feet.
Hole 4—300 feet north of No. 3; thickness 8 feet.
Hole 5—300 feet north of No. 4; thickness 2 feet. Sedge-peat.
Hole 6—300 feet north of No. 5; no peat.
Hole 7—300 feet north of No. 6; thickness 4 feet.
Hole 8—300 feet north of No. 7; thickness 10 feet. Poor quality at bottom.
Hole 9—300 feet north of No. 8; thickness 6 feet.

Analysis 80 (page 77) represents this sample. The deposit is of no commercial value as a source of peat fuel, but large crops of hay are cut on the bog.

DODGE COUNTY

There are no good peat deposits in Dodge County. The only marshy areas occur along the west border of the county, and the peaty material there is a black muck containing more mineral soil than organic matter. It is only about 2 feet thick. There are four such areas along the west edge of the county; one in sec. 30, Ellington T. (108N.; R. 18W.); one in sec. 7 and another in sec. 31, Claremont T. (107N.; R. 18W.); one in secs. 5 and 6, Ripley T. (106N.; R. 18W.); and one in sec. 19, Westfield T. (105N.; R. 18W.).

A deposit of peat 20 feet thick was reported in secs. 15 and 16, T. 106N.; R. 16W. This was found to be much less than 20 feet thick, and to consist of a narrow belt of soily muck along a small stream. None of these deposits are of any value for peat fuel. They can, however, be drained and the land used for agricultural purposes.

DOUGLAS COUNTY

There are no large peat areas in Douglas County, but numerous small bogs occur, a few of which contain nearly 1,000 acres. The largest bogs are in Spruce Hill and Miltona townships in the northeast corner of the county, and Hudson and Orange townships in the southeastern corner. Many more small bogs occur scattered throughout the county. Most of these small bogs occur around the shores of lakes, of which there are a great number.

The peat bogs are of both the muskeg and meadow, or marsh, types but the latter predominate. The muskegs are usually heavily timbered with tamarack and spruce, and the peat in them is shallow. On the other hand, the peat in some of the meadows and marshes is 8 to 10 feet deep, and of excellent quality for fuel and other purposes. The total area of the peat deposits in Douglas County, having an average depth of 6 feet, or more, is approximately 5,000 acres. Typical peat deposits of both types were studied and sampled at various localities in the county. The detailed descriptions of these bogs are given below.

FLORADA

Locality 130.—Sedge-grass meadow 1½ miles east of Florada station on the Soo railroad and 7 miles southeast of Alexandria. This marsh represents a filled lake. The peat is underlain by marl which, in turn, is underlain by sand. The marsh covers an area of about 900 acres over which the average thickness of the peat is approximately 7 feet. The maximum thickness indicated by test holes is 10 feet. The peat in the northern part of the bog is brown, rather fibrous, and is composed mostly of grass and sedge remains. It is free from shells and silt to a depth of 8 feet and is underlain by at least 5 feet of marl. The south half of the marsh contains the same depth and type of peat, but the material below a depth of 3 or 4 feet contains numerous small shells and is somewhat marly. There is also a 6-inch layer of marl on top of the peat in this portion of the marsh. The entire area is underlain by marl.

Samples were collected from the east edge of the bog to the large drainage ditch running north and south through the center of the bog; then southward along this ditch to the south edge of the bog. The samples were thoroughly mixed in order to obtain an average.

Analysis 81 (page 77) shows the composition of this sample. The marsh is well drained and has a smooth surface. It would be easily worked, and would be an attractive deposit if the peat were more uniform in character. The north half of the marsh has the best fuel peat. The marl is impure and peaty, but could be used as a fertilizer.

MILTONA

Locality 131.—Open sedge-grass meadow 1 mile south of Miltona station on the Soo railroad. This deposit is a filled lake, and the peat is underlain by sandy muck. The area is about 50 acres. The peat is 8 to 9 feet thick in the center of the bog, but the average thickness is only about 7 feet. The character of the peat is brown, firm, and rather fibrous. It is of uniform texture and quality, but the color changes from brown to black near the bottom of the deposit. It is composed almost entirely of sedge and grass remains. Samples were taken from two test holes, one near the edge of the bog, and the other in the center.

Analysis 82 (page 77) represents this peat. This bog could easily be drained and developed. Its smooth, open surface, its accessibility, together with a considerable thickness of peat of uniform character, make it an attractive deposit for the location of a peat fuel plant.

Locality 132.—Tamarack swamp 1¼ miles southeast of Miltona station on the Soo railroad. This deposit has been built up on a wet, swampy surface. The peat is underlain by sandy muck. There is an area here of about 1,000 acres over which the peat is about 5 feet thick. In character, the peat is brown near the top of the deposit, and rather fibrous and black near the bottom. Sedge and grass remains predominate. There is some woody fibre in the peat but not much moss. Two test holes were sunk near the northwest corner of sec. 31. One of these holes was located near the edge of the bog at the side of the wagon road, and the other hole 200 yards east of this point.

Analysis 83 (page 77) represents this sample. Conditions are not favorable for the development of a peat fuel plant on this bog. The trees are too large and numerous for cheap clearing.

PARKERS PRAIRIE

Locality 133.—Open marsh or meadow about 3 miles south of Parkers Prairie, and 1 mile west of the Soo railroad. Sedges (wire-grass), grasses, and reeds are the predominating plants on the bog, which is a filled lake. The peat is underlain by 1 foot of black muck which rests upon sandy till.

The area comprises about 160 acres of peat, with an average thickness of 7 feet. The peat is brown, fibrous, rather fluid and free from impurities, and is made up chiefly of the remains of sedges and grasses. Two test holes were sunk, the first hole 100 yards from the east edge of the bog; and the second in the center of the bog, both on the line between secs. 3 and 10, T. 130N.; R. 37W.

Analysis 84 (page 77) shows the composition of the peat which is of excellent quality for fuel. Considerable drainage would be necessary before the bog could be developed, as there were 12 inches of water on the surface at the time of inspection.

FARIBAULT COUNTY

The surface of Faribault County is covered with glacial drift, and, with the exception of the Kiester Hills, which stretch from northwest to southeast across the county, it is one of the most level in the state of Minnesota. The northern part of the county was once the bottom of an ancient lake of glacial times which is called Lake Minnesota.[76] The region is drained by the Blue Earth River and its tributaries. The Blue Earth rises in northern Iowa and flows northward across Faribault County in a valley about 100 feet below the general level of the surrounding country.

There are several rather large peat deposits in the county but in none of them is the peat more than four feet deep, while the average depth is only one or two feet. Most of these peat bogs have been drained and the land is used for agricultural purposes. There are numerous small meadows and marshes scattered throughout 20 townships in this county, which contain shallow deposits of peat, most of which are not more than 1 to 1½ feet thick. Few, if any of these are of any value for peat fuel.

BLUE EARTH

Locality 102.—Sedge-grass marsh about 7 miles southwest of Blue Earth, and 1 mile east of Pilot Grove Lake (now dry). The vegetation of the marsh is divided into two zones: an inner zone of reed-grass, and an outer one of sedges and grasses. The peat is underlain by a few inches of black muck, and then by yellow clay. The deposit was formed beneath a shallow lake. The area includes about 100 acres of peat of an average thickness of 18 inches. The maximum thickness is not more than 2 feet. The peat is dark brown to black, silty, fibrous, and shows distinct stratification. It is composed chiefly of the roots, stems, and remains of cattails, reed-grass, sedges, and grasses. Many snail shells occur in the peat, and numerous fragments of shells of wild duck's eggs were found buried in the peat. Samples were collected along the drainage ditch which crosses the bog from north to south.

Analysis 85 (page 77) represents this bog. The area will soon be drained and plowed for crops, as has already been done with the old bed of Pilot Grove Lake which was planted with corn.

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[76] N. H. Winchell, Final Report Geological and Natural History Survey of Minnesota 1:460-61. 1882.

FILLMORE COUNTY

There is no peat in Fillmore County.

FREEBORN COUNTY

Freeborn County, the southern limit of which forms a part of the Iowa-Minnesota boundary, is situated in the south central part of the state. It consists of twenty townships (720 square miles) and is one of the richest farming communities of southern Minnesota. Freeborn County contains the most extensive peat marshes in southern Minnesota, but none of these are deep. The peat averages 2 or 3 feet thick, and for this reason is unsuited to the manufacture of fuel on a commercial scale. Practically all of the land could be reclaimed for agricultural purposes.

The existence of peat in Freeborn County has long been known, and was noted by Winchell in his Final Report of the Minnesota Geological Survey. No attempts to utilize these deposits have been made, however, and at the time of this investigation no detailed information was available. The results of an investigation of the marshy land of the county show that the marshes lie chiefly in the east half of the county, and that nearly all of the marshes contain deposits of peat, but these deposits are for the most part shallow. The marshes are chiefly of the open grass-sedge type, with a few small ones which represent filled shallow lakes, or the peat-filled arms or bays of existing lakes. The peat in these marshes is composed of the remains of the same types of plants as those which are now found growing on the surface, namely grasses, sedges, reeds, cattails, etc.

The largest deposits of peat lie in Geneva, Riceland, Newry, and Moscow townships. Another large peat deposit, called the Hayward marsh, occurs in the eastern part of Hayward Township and extends for a short distance into Oakland Township. A third peat marsh of considerable area lies in the extreme southern part of the county in Freeman Township and extends southward into Iowa.

In addition to the three very large marshes named above, there are many small peaty areas, ranging from a few acres up to one hundred acres, scattered throughout the county. These are all too small to be of any value for peat fuel, and were not sampled. The majority of these smaller peat marshes, which are all shallow, have been drained and are now under cultivation. The principal crops grown on these reclaimed peat bogs are hay, wheat, barley, oats, and corn. Because of the continued draining and cropping of these marshy tracts, a large number of areas shown on the original government township plats as swamp land, and even as open ponds and lakes, have now completely changed in character, and hardly a trace of their original marshy nature remains, except the peaty soil with which they are covered. Descriptions of the three largest peat deposits in Freeborn County, namely, the Geneva marsh, the Hayward marsh, and the Freeman marsh are given below.

ALBERT LEA

Locality 94.—Open marsh known as Hayward marsh, in Hayward and Oakland townships, 10 miles east of Albert Lea. The original (natural) vegetation is nearly all gone from this marsh, and most of the area has been plowed, and hay and other crops are being raised on it. Toward the east edge of the marsh, where a small area of natural vegetation remains, sedges and grasses predominate. The peat is underlain by yellow plastic clay. The deposit accumulated on a flat, undrained, marshy tract, and has been built up by successive growths of peat-forming plants.

The area of the marsh is about 5 square miles, and the peat has an average thickness of 2½ feet. It consists of dark brown to black, stratified, fibrous, or flaky peat, which gives an acid test with litmus paper. It is composed chiefly of the remains of sedges, cattails and rushes. There are many snail shells in the bottom layers.

The locations of the test holes are as follows:

Hole 1—At S. ¼ corner sec. 10, T. 102N., R. 20W.; thickness 2 feet. Surface is plowed.

Hole 2—¼ mile east of No. 1 along road on section line; thickness 2½ feet. Surface is plowed.

Hole 3—Corner secs. 10, 11, 14, and 15, ¼ mile east of No. 2; thickness 2½ feet. At ditch.

Hole 4—¼ mile east of No. 3 along road; thickness 2 feet. Surface is plowed.

Hole 5—At S. ¼ corner sec. 11, along road; thickness 3 feet. Wheat planted.

Analysis 86 (page 77) represents this sample. The land is more valuable for agricultural purposes than for the peat. Good crops of wheat, timothy, and clover were growing on the marsh at the time of inspection. The land has been drained by large ditches with small laterals every quarter of a mile.

Locality 94a.—This is a part of the same marsh as just described under Locality 94. Additional samples were taken as follows:

Hole 1—¼ mile west of corner of secs. 11, 12, 13, 14; T. 102N., R. 20W. Thickness 2½ feet. Wheat growing.

Hole 2—Corner secs. 11, 12, 13, 14; same twp.; thickness 2 feet. Surface is plowed.

Hole 3—¼ mile east of No. 2. Thickness 2½ feet; plowed.

Hole 4—At south ¼ corner sec. 12. Thickness 2½ feet; plowed.

Hole 5—¼ mile east of No. 4. Thickness 2¼ feet; sand in peat.

Peat was collected along the ditch from each of the above described 5 localities, and all mixed in a sample sack in order to obtain an average.

Analysis 87 (page 77) represents this sample. This part of the marsh has been cleared and plowed, and has been used for several years for growing hay. The peat is well drained and firm. The thickness of the peat before drainage was probably 3½ feet.

Locality 94b.—This represents the eastern portion of the Hayward marsh, and is a continuation of the sampling on the same marsh as just described under localities 94 and 94a.

Test holes were located as follows:

Hole 1—At southeast corner, sec. 12, T. 102N., R. 20W.; thickness 2 feet. Very sandy peat.
Hole 2—¼ mile east of No. 1; thickness 1½ feet.
Hole 3—At S. ¼ corner sec. 7, T. 102N., R. 19W. Muck.

Peat was collected along the ditch from the above localities and mixed. Analysis 88 (page 77) represents this sample. The peat becomes more sandy toward the east edge of the marsh, where it grades into muck.

Locality 95.—This area, known as the Geneva marsh, is located about 12 miles north of Albert Lea, and occupies parts of Geneva, Newry, Riceland, and Moscow townships. It is by far the largest marsh in the county, and one of the largest in southern Minnesota. The marsh is of the open grass-sedge type. The natural vegetation has nearly all been destroyed. Most of the marsh has been plowed and planted with grain. The remainder is used for pasture. The small areas of natural vegetation which remain show grasses, sedges, tall reed-grass, and many weeds which are characteristic of dry ground, and which have recently sprung up since the big drainage ditches were completed. The peat has been built up on a flat undrained surface, and is underlain by 2 feet of heavy, black clay, and that by yellowish plastic clay.

The total area of the land covered by peat is about 10 square miles. Much of the marsh is not included in the above estimate which does not take into account large areas of black muck in which the amount of mineral soil is so great that the material can not be classified as peat. The average depth of the peat in this area is about 2 feet. In the old bed of Rice Lake, the peat shows a thickness of 4 feet at some places. It is chiefly composed of the remains of sedges, grasses, reeds, and cattails. No moss could be found.

Samples were collected along the main east-west road which runs a quarter mile north of the south boundaries of secs. 13 and 14. Test holes were put down every ¼ mile across the marsh, and peat samples were collected from top to bottom of each hole, and mixed.

Analysis 89 (page 77) represents this peat. While this great marsh is nearly all covered with peat, the deposit is so shallow that it could not be used for peat fuel. On the other hand, it will be possible to utilize most of the land for agriculture. The reclamation of this marsh furnishes a good example of what may be done with numerous other areas of peat-covered land in Minnesota.

Locality 96.—North part of Geneva marsh just described under Locality 95. This part of the marsh lies 6 miles east of Clarks Grove on the Chicago, Rock Island, and Pacific railroad in sec. 35, T. 104N.; R. 20W. Samples were taken at numerous places along the drainage ditch, which parallels the wagon road running north and south across the bog ¼ mile east of the west edge of sec. 35, T. 104N.; R. 20W.

Analysis 90 (page 77) represents this portion of the bog. The peat is so shallow here that it can be mixed with the sub-soil by deep plowing.

GLENVILLE

Locality 97.—Open marsh about 4 miles south of Glenville station, on the Chicago, Rock Island and Pacific railroad. Grasses, sedges, and cattails predominate on the marsh. The peat is underlain by very sticky, plastic clay. The deposit has been built up on a low, undrained, marshy surface. The total area of the marsh comprises several square miles, but only about 1,000 acres is covered with peat. The average thickness of the peat is 2 feet and the maximum thickness observed from test holes, was 4 to 5 feet. The peat is black, silty, and somewhat plastic near the bottom of the deposit, where it grades into muck. Samples were taken from test holes along an east-west line near the north edge of sec. 36.

Analysis 91 (page 77) represents this peat. The land is valuable for agricultural purposes, and with better drainage, which would be easy to accomplish, it could all be used for farming.

GOODHUE COUNTY

There is no peat of commercial value in Goodhue County. The few wet areas in the county consist of only one or two acres each, and the soil is black muck.

GRANT COUNTY

There is no peat in Grant County of sufficient depth to merit special mention. All of the peaty areas could be plowed, and the peat mixed with the subsoil, after the land is drained.

HENNEPIN COUNTY

The surface of Hennepin County exhibits hilly topography due to the presence of numerous moraines. The irregular, morainic hills are separated by depressions and basins, many of which are sites of lakes and swamps. Most of the swamps and marshes in the county contain peat deposits, and peat is now actively forming in and around many of the small lakes.

The total area of Hennepin County is 397,739.8 acres, of which 44,821.2 are covered by water and 352,918.6 acres are land. The original swamp area in the county was much larger than the present wet land area, since many of the marshes and swamps have been drained and converted into first-class land. This is especially true in the vicinity of Minneapolis.

There are no very extensive peat deposits in the county, but numerous small peat bogs occur throughout the area, especially in the vicinity of Lake Minnetonka and in the southern portion of the county, between Minneapolis and the Minnesota River, which forms the south boundary of the county. The peat bogs consist of three types: (1) small tamarack muskeg swamps; (2) open sedge bogs; and (3) river flood-plain marshes. Many of these peat bogs contain at least 75 acres over which the peat is of workable depth; i.e., at least 6 feet thick, and the material is generally of good quality and would make good peat fuel. Figure 2 shows a number of typical small bogs in southern Hennepin County.

Detailed descriptions of some of the Hennepin County peat deposits are given below.

ST. BONIFACIUS

Locality 246.—Quaking bog 1½ miles northeast of St. Bonifacius; W½ sec. 27, and E½ sec. 28, T. 117N., R. 24W. Sedges, cattails, reeds, and grasses predominate. The peat is underlain by coarse sand and the deposit represents a filled bay, or arm, of Lake Minnetonka.

The area contained within this bog is about 640 acres. The average thickness of the peat is approximately 8 feet with a maximum thickness of 10 feet as indicated by test holes. The top layer (1 foot) of peat is dark brown, fibrous, and somewhat sandy. The second layer (1 foot) is decomposed, and at 8 feet it is plastic, almost black, and contains considerable mineral soil. The peat is made up mostly of sedge and grass remains. Test holes were located as follows:

Hole 1—500 feet east of margin of bog; thickness 8 feet.
Hole 2—500 feet east of No. 1; thickness 10 feet.
Hole 3—500 feet east of No. 2; thickness 10 feet. Near lake shore.
Hole 4—500 feet east of No. 3; 500 feet west of margin; thickness 6 feet. Near island.

Analysis 92 (page 77) represents this sample. There are numerous small meadow bogs southwest of this one, some of which are connected by narrow peat-filled meadows extending along water-ways. The bogs all lie in morainic depressions in a hilly region.

MINNEAPOLIS

Locality 247.—Open bog of the meadow type, ½ mile west of Cedar Lake, near the west city limits of Minneapolis, in sec. 11, T. 117N.,

R. 21W. This deposit represents a peat-filled lake. The vegetation consists mostly of sedges with a little sphagnum moss.

The area of the bog is about 200 acres, and the average thickness of the peat is approximately 12 feet, with a maximum thickness of 16 feet. The top 4 feet of the deposit is composed of brown, fibrous peat. From 4 to 8 feet, gray, marly peat occurs, and below at a depth of 8 feet, green pond peat is found. Test holes were located along an east-west line corresponding with the south boundary of the north row of forty's in the section, as follows:

Hole 1—500 feet west of margin of bog; thickness 8 feet. Top 4 feet fibrous; gray peat below.
Hole 2—500 feet west of No. 1; thickness 12 feet. Bottom 4 feet is green pond peat.
Hole 3—500 feet west of No. 2; thickness 13 feet. Bottom 5 feet is garden pond peat.
Hole 4—500 feet west of No. 3; 500 feet from west margin; thickness 9 feet. Bottom 1 foot is green pond peat.

Analysis 93 (page 77) represents this deposit. The bog lies adjacent to a railroad and is well situated for development.

EXCELSIOR

Locality 248.—Bog of the open meadow type in the NW¼ sec. 3, T. 117N., R. 21W. along the road to Lake Minnetonka. The vegetation at the present time is not the original vegetation of the bog. Most of the area is now used as a hay meadow. At the southeast edge of the bog a few tamarack trees are still standing. The peat is underlain by clay, and in some places by coarse sand. The deposit probably represents a peat-filled lake.

The area of the meadow is about 200 acres, and the peat has an average thickness of approximately 12 feet. The top 2 feet of the deposit consists of red-brown, fibrous peat. From 2 to 4 feet the peat is more fluid and decomposed. At 5 feet, gray, marly peat, containing shells, was encountered. At 7 feet, the gray peat shows well preserved brown sedge remains. At 10 feet the peat changes to black muck. Charred stumps at a depth of 2 feet show that the bog has been burned.

Test holes were located along a north-south line through the middle of sec. 3, from the center to the north boundary of the section, as follows:

Hole 1—500 feet north of road along ditch and 500 feet north of the margin of the bog; thickness 12 feet.
Hole 2—500 feet north of No. 1; thickness 13 feet.
Hole 3—500 feet north of No. 2; thickness 11 feet.
Hole 4—500 feet north of No. 3; 50 feet from north edge; thickness 6 feet.

Analysis 94 (page 77) represents this peat. This bog, like that described under Locality 247, is typical of a large number of small bogs in this vicinity. The peat, except in the upper 4 or 5 feet of the deposit, is too marly to be good for fuel.

Locality 249.—Bog just west of that described under Locality 248, along Excelsior Road. This bog is a combination of muskeg and open sedge-grass marsh. Nearly all types of common Minnesota swamp vegetation are found growing on the surface of the bog. Around the edge of the bog low shrubs and bushes, such as swamp birch, willows, and poplars occur. A few cattails were noted. Moss, sedges, and grasses also occur, and about 60 acres of the area is covered with 2- to 4-inch tamarack trees. The peat is underlain by fine sand, and the deposit represents a peat-filled lake.

The bog comprises an area of about 300 acres. About 100 acres is covered with good, brown peat 6 feet thick; another 100 acres contains brown peat 3 feet thick, underlain by 8 feet of gray marly peat; and the remainder of the area contains gray peat 10 feet thick, underlain by 8 feet of green pond peat. The brown peat consists chiefly of the remains of sedges, cattails, and reeds. The gray, marly peat contains sedge remains, but most of it is so decomposed that it is difficult to recognize any plant remains. The bottom green peat consists chiefly of pondweeds and other aquatic plants.

Test holes were located along an east-west line, 2,000 feet north of the south boundary of sec. 4, beginning at the west edge of the section as follows:

Hole 1—500 feet east of west margin of the bog; thickness 6 feet. Good, brown peat.
Hole 2—500 feet east of No. 1; thickness 6 feet.
Hole 3—500 feet east of No. 2; thickness 8 feet. Brown peat, 4 feet; gray, marly peat, 1 foot.
Hole 4—500 feet east of No. 3; thickness 12 feet. Brown peat, 3 feet over 9 feet of gray peat.
Hole 5—500 feet east of No. 4; 500 feet from west margin; thickness 18+ feet. Brown peat, 1 foot, underlain by 10 feet of gray peat which is underlain by 7 feet of green pond peat.

Analysis 95 (page 77) represents this deposit. The peat is too variable in composition and character to be workable. The good brown peat on top is too shallow to be worked, and the gray and green peat at depth contains too much ash for fuel.

HOPKINS

Locality 250.—This is an open meadow along a stream valley, ½ mile south of Hopkins. Sedges and grasses constitute the dominant vegetation, but a few tamaracks were noted, and also a little moss. The peat is underlain by coarse sand.

This bog covers an area of about 160 acres, and the average thickness of the peat is approximately 8 feet. The peat in the upper layers of the deposit is fibrous, and of a dark brown color, while that near the bottom is of a gray color, plastic, marly, and contains many shells. The upper layers of peat are composed mostly of sedges and grasses with a few reeds, cattails and bulrushes.

Test holes were located along the section line between sections 28 and 29, starting at the corner of sections 28, 29, 32, and 33 as follows:

Hole 1—200 feet north of margin of bog. Corner secs. 28, 29, 32 and 33; thickness 8½ feet. Gray peat encountered at 6 feet in depth.
Hole 2—500 feet north of No. 1; thickness 9 feet. Mossy peat 1 foot thick on top followed by 3½ feet of sedge peat underlain by 4½ feet of gray, marly peat.
Hole 3—500 feet north of No. 2; thickness 9 feet; brown sedge peat, 3 feet.
Hole 4—500 feet north of No. 3, 500 feet from margin; thickness 8 feet. Practically all dark gray marl with shells.

Analysis 96 (page 77) represents the average of samples taken from this deposit.

EDEN PRAIRIE

Locality 252.—This is an open meadow about 1½ miles west of Eden Prairie, along the Minneapolis and St. Louis railroad. The peat deposit is probably a filled lake or pond. The peat is underlain by sand. The original vegetation has been destroyed, and the bog is now used as pasture. The presence of a few swamp-spruce trees, and the composition of the peat show that the bog was probably originally a spruce swamp.

The area of the peat deposit is about 100 acres, and the average thickness of the peat is about 8 feet with a maximum thickness of 12 feet as indicated by test holes. The peat is light to dark brown in color, and fibrous, except near the bottom, where it is well decomposed. A small thickness of green pond peat occurs near the bottom of the deposit.

Test holes were located along a line extending southeast across the middle of the bog as follows:

Hole 1—500 feet southeast of margin; thickness 8 feet. Top 6 feet, brown peat underlain by 2 feet of gray peat.
Hole 2—500 feet southeast of No. 1; thickness 12 feet. 6 feet brown peat; 4 feet gray peat; 2 feet green peat at bottom.
Hole 3—500 feet southeast of No. 2; thickness 10 feet.
Hole 4—500 feet southeast of No. 3; 500 feet from margin; thickness 8 feet.

Analysis 97 (page 77) represents this deposit. The bog is typical of many in this locality, in all of which a few tamarack or spruce trees may be seen, showing that they were originally muskegs. This deposit lies in a situation favorable for development.

HOUSTON COUNTY

Houston County lies in the driftless area of southeastern Minnesota, and contains no peat deposits.

HUBBARD COUNTY

Hubbard County, which lies just west of Cass County in north central Minnesota, contains numerous small peat bogs, but no large swamps comparable to those which occur in the counties to the north. Most of the swampy, or peaty, areas in Hubbard County occur around lakes or along streams. The United States government reservoir dam on Leech Lake River backs up the water in the streams flowing into Leech Lake and is the cause of some extensive areas of overflowed land, which can not be easily reclaimed.

Hubbard County contains about 77,000 acres of wet and overflowed land, but not more than about one third of this area, or 26,000 acres, is covered with peat, and most of this peat is very shallow, the average depth being less than 5 feet. A large part of the remaining two thirds of the wet land area is covered with black muck, containing a large percentage of mineral soil. This is especially true of the marshes and overflowed areas along stream courses.

There are both open grass marshes and timbered muskeg swamps in Hubbard County. About 60 per cent of the peat land is open marsh, and the remaining 40 per cent is muskeg. Several typical peat deposits were studied and sampled and the results are given below.

BENEDICT

Locality 112.—This is a tamarack-spruce-cedar swamp, located ¼ of a mile west of Benedict station, along the Minnesota and International railroad on the west side of the tracks. In addition to the trees mentioned, sphagnum and heath shrubs (Labrador tea) are the predominating plants on the bog. Tamarack, spruce, and cedar trees are numerous. The peat is underlain by coarse white sand. The deposit is evidently a filled shallow lake, and the surface of the bog has been subsequently built up by successive layers of dead vegetation.

This bog covers an area of about 900 acres, and contains peat showing an average thickness of approximately 8 feet. The peat is black and decomposed. The bottom 18 inches of the deposit is greenish and contains numerous small snail shells. The peat is composed mostly of the remains of sphagnum moss, tamarack, and spruce trees.

Samples were collected from two holes sunk near the edge of the open part of the bog.

Analysis 98 (page 78) represents this peat.

Locality 113.—This is a typical muskeg ½ mile south of Benedict along the Minnesota and International railroad. The vegetation consists chiefly of tamarack, a few small spruce, sphagnum and polytrichiem moss, heath shrubs, cotton-grass, and sedges. The deposit represents a filled lake. At the deepest place in the bog, the peat is underlain by soft, blue, clayey mud. The real bottom consists of sand.

The area contains only about 30 acres, and the peat varies in thickness from 18 to 20 feet. In the upper 12 feet of the deposit, the peat is dark brown to yellow-brown, and well decomposed. There is a fibrous mossy layer on top. Below 12 or 14 feet the material consists of soft, plastic, greenish yellow pond peat. The upper 12 feet is composed chiefly of sphagnum and heath remains, with many roots and stumps of wood. Below 12 feet the peat consists chiefly of remains of sedges, grasses, and pondweeds. There are no stumps or roots below 12 feet in depth. The location of the test holes is as follows:

Hole 1—50 feet north of south edge of bog along railroad; thickness 7 feet. Black decomposed peat.
Hole 2—150 feet north of No. 1; thickness 20+ feet. Rods not long enough to reach bottom.
Hole 3—200 feet north of No. 2; thickness 16 feet. Fluid, blue mud beneath peat.
Hole 4—Halfway between center and north edge of bog along railroad; thickness 18 feet. Green pond peat below 12 feet.
Hole 5—North edge of bog; shallow. Sphagnum only.

Analysis 99 (page 78) represents the average of this deposit from top to bottom.

Analysis 100 (page 78) represents the upper 5 feet of the deposit, sampled separately in order to show the composition of the typical sphagnum peat. By comparing Analyses 99 and 100, the effect produced on the composition of the peat by including green pond peat may be seen.

The Minnesota and International railroad track, which is built across the middle of this bog on a heavy gravel fill, has caused the surface of the bog on both sides of the track to break, and the peat has been heaved, or pushed up in a ridge along the break 10 feet above the normal level of the surface. According to reports, a trestle was built across the bog in constructing the fill. As the weight of the fill accumulated, the peat surface, which apparently forms a floating mat in this bog, suddenly broke, and the fill disappeared entirely, carrying trestle and track with it. The bog still quakes violently when trains cross it. The top 4 feet of the peat from this bog consists entirely of clean sphagnum moss and would make excellent peat litter or packing material. Plate XVII, Figure B, shows a photograph of a part of this bog.

ISANTI COUNTY

According to the State Engineer's report[77] there were originally in Isanti County 20,000 acres of swamp lands. About half of this area,

[77] George A. Ralph, Engineer's Report on Topographical and Drainage Surveys in Minnesota. 1906.

or 10,000 acres, is covered with peat. The deepest and most extensive peat bogs occur in the extreme northwest corner of the county in Dalbo Township. About half of this township is swampy.

Many other smaller bogs and marshes are scattered throughout the county especially in the southern portion. Most of these were originally small muskeg swamps, but the tamarack and spruce trees have either been burned or cleared off, and the areas are now open sedge marshes and are used for hay meadows or pasture.

Two of the best peat deposits in the county are described below.

DALBO TOWNSHIP

Locality 224.—This is a bog of the open meadow type which occupies portions of secs. 2, 3, 4, and 5, T. 37N., R. 25W. It is 22 miles from the nearest railroad. The vegetation of the bog consists chiefly of sedges (*Carex*), grasses ("red top" and "blue joint"), goldenrod, and reed-grass. There are indications of a former growth of tamarack trees, although none are now growing on the bog. The deposit was formed by the filling in of a shallow pond or marsh.

The area of the bog is about 2 square miles, and the peat has an average thickness of about 5½ feet. The top 3 feet is brown, fibrous peat, which is undecomposed. The lower half of the deposit consists of straw-colored, fibrous peat, with plant remains well preserved.

Test holes were located along a north line through the center of section 4, as follows:

Hole 1—Middle of north boundary of sec. 4 at quarter corner; thickness 3 feet.
Hole 2—¼ mile south of No. 1; thickness 5 feet.
Hole 3—¼ mile south of No. 2; thickness 7 feet.
Hole 4—¼ mile south of No. 3; thickness 6 feet.

Analysis 101 (page 78) represents this deposit. This marsh was being cleared at the time of visiting the locality, preparatory to cutting sedges ("wire grass") for the Crex Carpet Company. The "wire grass" is manufactured into grass rugs and carpets.

PRINCETON

Locality 245.—This bog covers most of secs. 8, 9, 10, 11, 17, and 18, T. 37N., R. 25W. The bog is a combination of muskeg and open sedge marsh, the open portion probably representing a burned area. The peat deposit is underlain by sand, and it has been built up above an old peat-filled lake by successive growths of swamp vegetation. The dominant type of vegetation in the south half of the bog consists of sedges, of which there is a luxurious growth. In places, sphagnum moss may be seen at the sedge roots. The north half of section 9 is a typical heath bog, with sphagnum moss and a few spruce trees.

The area included within the bog is about 4 square miles. The average thickness of the peat is probably 10 feet. The peat is dark to light brown, and fibrous to decomposed. The peat is darker in color and more fibrous near the top. The texture is fairly uniform.

Test holes were located along a north line from the center of sec. 9, as follows:

Hole 1—At mid-point on north edge of section at half corner; thickness 6 feet.
Hole 2—1,000 feet south of No. 1; thickness 12 feet; very fluid peat.
Hole 3—1,000 feet south of No. 2 at a spruce grove; thickness 14 feet. Bottom 2 feet is green peat.
Hole 4—1,000 feet south of No. 3; thickness 14 feet.
Hole 5—1,000 feet south of No. 4; 200 feet from south margin; thickness 10 feet.

Analysis 102 (page 78) shows the composition of this peat.

While the top 8 feet of the deposit consists of good fuel peat, the bog is not an attractive one for development at present because of its inaccessibility. The Crex Carpet Company has contracted for the sedge or wire-grass crop on this area. Mr. Orlando P. Merrill, the owner of the portion of the bog which was sampled and described above, has made some fuel of excellent quality from the peat.

ITASCA COUNTY

Itasca County is one of the four largest peat land counties in the state, the other three being Beltrami, Koochiching and St. Louis. The total swamp land area of Itasca County is 590,600 acres.[78] About two thirds of this area, or 393,732 acres, contains peat. Not all of this peat is workable. In many of the swamps in the county the peat is only one to three feet thick. There are, however, at least 250,000 acres of land covered with peat at least six feet thick. The largest swamps lie in the northern part of the county, and form portions of the immense peat deposits which extend north and westward across much of Koochiching and Beltrami counties and into Roseau County. The northern and central parts of the county have a somewhat rolling surface, dotted with numerous lakes, and with many swamps, some of which are extensive.

The swamps in this county are, on the average, more heavily timbered than those in the counties to the westward, and in this respect they resemble the St. Louis County peat swamps. The timber is typical of the northern muskegs and consists chiefly of small tamarack, spruce, and cedar trees, the relative abundance of which is in the order named. There are numerous open heath bogs within the tamarack-spruce swamps, and, as in the adjoining counties, the peat in these open bogs is deeper than in the forest areas.

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[78] Annual Report Minnesota State Drainage Commission, p. 139. 1913.

Much of the peat covered area is at present inaccessible, but there are some large deposits of excellent fuel peat adjoining railroads which were examined and tested in detail, and the results are given in the following pages. One of the largest and most uniform peat bogs lies north of Deer River. Other important accessible deposits occur along the Great Northern railroad from Wawina to Swan River.

There are some extensive open treeless sedge-grass marshes along the Mississippi River which contain peat deposits, but these were found to be rather silty and high in ash. The problems to be overcome in draining these river-flat marshes, which are subject to overflow from the river during periods of high water, should be considered in any attempt to reclaim this land or to utilize the peat.

SWAN RIVER

Locality 114.—This is a part of a big muskeg swamp which surrounds the village of Swan River. The deposit probably represents a filled, shallow lake or marsh. The sphagnum with which the surface is now covered has only recently appeared, for there is almost no sphagnum in the peat which is underlain by yellow sand. The vegetation consists chiefly of heaths, tamaracks, sedges, sphagnum, blueberry, and grasses. The tamarack trees are mostly dead.

The total area of this bog is many square miles, but the area immediately surrounding Swan River consists of several square miles. The average thickness at this locality is about 5 feet, with a maximum thickness of 7 feet, and a minimum of 1½ feet as indicated by test holes. The peat is brown, rather fluid, soft, and decomposed. All except the top 2 feet consists of sedges and grasses. The upper part of the deposit contains some moss.

The location of the test holes is as follows:

Hole 1—1,000 feet east of the section house along railroad at Swan River; thickness 5 feet. Fluid sedge-peat.
Hole 2—1,000 feet west of No. 1 at section house; thickness 2 feet. Fluid sedge-peat.
Hole 3—1,000 feet west of No. 2 at engine house; thickness 2½ feet. Fluid sedge-peat.
Hole 4—1,000 feet west of No. 3 at switch; thickness 7 feet; top is mossy.
Hole 5—1,000 feet west of No. 4; thickness 5½ feet.
Hole 6—1,000 feet west of No. 5; thickness 7 feet. Light yellow brown peat.
Hole 7—1,000 feet west of No. 6; thickness 6 feet.
Hole 8—600 feet west of No. 7 at edge of bog; thickness 1½ feet.

Analysis 103 (page 78) represents this portion of the deposit, which is well situated for development and can be easily drained and worked.

Locality 115.—This is another portion of the same bog just described under Locality 114, but is separated from Locality 114 by islands of higher land. The average thickness of the peat here is only 2 or 3 feet.

It is brown and fibrous, and is composed chiefly of heath and sphagnum remains in the upper layers, with sedge remains below.

The location of the test holes for this sample is as follows:

Hole 1—¼ mile southeast of station; thickness 2½ feet.
Hole 2—1 mile southeast of station; thickness 3 feet.
Hole 3—1⅛ miles southeast of station; thickness 2 feet.
Hole 4—¼ mile southeast of station; thickness 2½ feet.

Analysis 104 (page 78) shows the composition of the peat in this portion of the bog. The bog here is too shallow to be used for peat fuel, and the bottom is too sandy to make good soil.

WAWINA

Locality 118.—This is also another portion of the same bog just described under localities 114 and 115. This sample was taken at mile post 86, two miles east of Wawina station on the Great Northern railroad. The vegetation here consists chiefly of sphagnum, heath shrubs, sedges, and small tamaracks. The average thickness of the peat is probably about 15 feet. It is brown, soft, and well decomposed.

Only one test hole was put down at this point and an average sample of peat was obtained from the top to the bottom of the deposit.

Analysis 105 (page 78) represents this sample.

From this point westward to Wawina the peat is all of good quality, but it gradually becomes shallower. At mile post No. 87 it may be seen in the sides of a ditch where it is 8 feet thick. At Wawina, which is on the west edge of the bog, there is no peat at the station, but 300 feet east of the station the peat is 4 feet thick. From this point on the edge of the bog the peat becomes thicker toward the east to mile post 85, where the maximum depth of 18 feet occurs. The best and deepest portion of the peat bog lies between mile posts 84 and 86. This bog is in an excellent location for development. The peat will make good fuel.

DEER RIVER

Locality 119.—The south edge of this large muskeg swamp lies about 5 miles north of Deer River. The county road extending north from Deer River, 1 mile west from the range line, crosses this swamp for a distance of 8 miles. The Minnesota and International railroad also cuts across the eastern part of the swamp from McVeighs' northwestward. Spruce trees, heath shrubs, sphagnum and polytrichiem moss, and cotton-grass form the commonest types of vegetation. The greater part of the area represents a built-up deposit formed on a flat, undrained area. The deeper portion of the swamp, where the brown peat is underlain by green pond peat, is a filled shallow lake, which occupied the center of this flat plain. After the lake became filled with peat, sphagnum moss invaded this newly formed swamp, and its surface was gradually built up 7 or 8 feet above the old lake level. The peat is everywhere underlain by a blue, sticky clay.

This muskeg covers an area of at least 20 square miles. The average thickness of the peat as indicated by the test holes included in this sample, is about 10 feet. The maximum thickness obtained was 16 feet. The peat is dark brown on top, greenish near bottom. Soft, rather fluid, and well decomposed. It is very uniform in texture. The upper 6 feet of the deposit contains numerous roots and pieces of wood. No moss was observed in the peat below a depth of 8 or 9 feet. Test holes were located as follows:

Hole 1—South edge of bog along north-south county road; thickness 2½ feet. Mossy.
Hole 2—¼ mile north of No. 1 at junction of east road; thickness 6 feet. Top 2 feet, mossy.
Hole 3—¼ mile north of No. 2; thickness 11 feet. Green peat near bottom.
Hole 4—¼ mile north of No. 3; thickness 16 feet. Green peat near bottom.

Analysis 106 (page 78) shows the average composition of the peat in this portion of the bog. This swamp contains one of the best fuel peat deposits in the state. The peat is homogeneous as to texture and composition; the vegetation is not too heavy for cheap clearing, and there are already large drainage ditches constructed along the roads crossing the swamp into which laterals can be drained.

Locality 119a.—This represents a continuation of the same muskeg as that described under Locality 119. This sample covers a distance of 1¼ miles along the road north of hole 4 of Locality 119. The exact location of these test holes is as follows:

Hole 1—¼ of a mile north of hole 4, Locality 119; thickness 14 feet. Greenish peat near bottom.
Hole 2—¼ mile north of No. 1; thickness 10 feet. No green peat.
Hole 3—¼ mile north of No. 2; thickness 7 feet. Upper 3 feet mossy.
Hole 4—¼ mile north of No. 3; thickness 8 inches. All moss.
Hole 5—¼ mile north of No. 4, near edge of bog; thickness 3½ feet. Mostly moss.

Analysis 107 (page 78) represents the average peat from these holes.

The peat throughout this portion of the bog is also uniform as to texture and composition. There is no green pond peat here, except around hole No. 1. Most of the peat is dark brown in color and consists of sphagnum, heath, tamarack and spruce remains.

Locality 119b.—This is also a continuation of the same muskeg as that described under localities 119 and 119a. This sample covers a distance of 3 miles along the road north of hole 5, Locality 119a. The sampling was discontinued at an island of high ground on the bog.

The locations of the test holes are as follows:

Hole 1—400 feet north of first island crossed by road, about 2,000 feet north of hole 5 of 119a; thickness 2 feet. Mostly moss.
Hole 2—¼ mile north of hole No. 1; thickness 11 feet. Uniform texture; well decomposed.
Hole 3—¼ mile north of hole No. 2; thickness 13 feet. Moss and sedge remains.
Hole 4—¼ mile north of hole No. 3; thickness 12 feet. Moss and sedge remains.
Hole 5—¼ mile north of hole No. 4; thickness 11 feet. Moss and sedge remains.
Hole 6—¼ mile north of hole No. 5; thickness 10 feet. Moss and sedge remains.
Hole 7—¼ mile north of hole No. 6; thickness 10 feet. Moss and sedge remains.
Hole 8—¼ mile north of hole No. 7; thickness 7½ feet. Moss and sedge remains.
Hole 9—¼ mile north of hole No. 8; thickness 6 feet. Mostly moss.
Hole 10—¼ mile north of hole No. 9; thickness 5 feet. Mostly moss.
Hole 11—¼ mile north of hole No. 10; thickness 5 feet. Mostly moss and heaths.
Hole 12—¼ mile north of hole No. 11; thickness 4 feet. Mostly mosses and heaths.
Hole 13—¼ mile north of hole No. 12, 400 feet from edge of second island of high ground; thickness 5 feet. Mostly mosses and heaths.

Analysis 108 (page 78) represents average composition of the peat from these holes. This part of the swamp is similar to the other portions. The peat is of excellent quality for fuel.

Locality 120.—This is a muskeg swamp 8 miles northeast of Deer River. The swamp covers an area of several square miles. The thickness of the peat was not determined. Only the upper 3 feet of the deposit was examined for peat litter. This upper portion of the deposit consists of fibrous, mossy, yellow-brown sphagnum peat.

Analysis 109 (page 78) shows the composition of the top fibrous peat. The sample was taken to determine the value of the upper part of this peat deposit for peat litter and packing material. It was found to be of good quality for such use, and a large amount of excellent material for these purposes can be obtained in this locality. The upper 3 feet of peat consists entirely of sphagnum moss.

COLERAINE

Locality 121.—This is a small but typical muskeg 1 mile west of Coleraine along the Great Northern railroad, on the north side of the tracks, and between the tracks and the wagon road. The bog is separated from a small lake by a high, narrow, morainic ridge of gravel. Spruce and tamarack trees, heath shrubs, sphagnum moss, cotton-grass, sedges, and cranberry bushes are the dominant plants in the bog. A typical 4-inch tamarack tree which was examined showed 92 rings. The peat is underlain by blue clay and coarse sand. The bog represents a filled lake.

The area of this deposit is only about 12 acres. The peat is unusually deep, the average thickness being more than 25 feet. The bottom of the peat could not be reached with the sampling rods except around the edges of the bog. The top 6 feet of the deposit consists of fibrous, brown, mossy peat. From 6 to 11 feet of peat is dark brown and decomposed. From 11 to 25 feet and deeper, the peat is of the typical, soft, greenish, pondweed variety.

The location of the test holes is as follows:

Hole 1—100 feet from east edge of bog; thickness 13 feet. Moss peat top. Green pond peat bottom 2 feet.

Hole 2—Center of bog; thickness 25+ feet. Cranberry and heath leaves at 7 feet. Green peat below 9 feet. Moss peat near top.

Hole 3—Center of bog, but nearer edge; thickness 21 feet. Coarse sand bottom. Pieces of wood found near bottom. A layer of logs at 6 feet. Green peat below 19 feet.

Hole 4—Near west edge of bog; thickness 7 feet. No green peat. All brown moss peat.

Analysis 110 (page 78) shows the composition of this peat.

Locality 122.—Bog 2 miles west of Coleraine; SE¼ sec. 35, T. 56N., R. 25W. Three stages in peat bog formation are represented in this one small deposit: (1) muskeg; (2) open sedge-heath bog; (3) a pond deposit. Around the pond typical vegetational zones of pond-lilies and sedges have been developed. (See Figure A., Plate XVII.) The pond is full of aquatic plants. In the muskeg, tamarack, spruce, heaths, sphagnum, swamp birch, cotton-grass, and sedges are found. In the open part of the bog sedges are dominant, but sphagnum and polytrichiem moss and liverworts are common. The peat is underlain by sand, and the deposit represents a partially filled lake. A floating sedge mat is rapidly being formed around the pond, which will soon be entirely covered over.

The area of the bog is only about 10 acres. The peat is from 15 to 20 feet thick, and is light brown, decomposed, and rather fluid.

Samples were collected from one hole located in the center of the open part of the bog.

Analysis 111 (page 78) represents an average of these samples. This is one of the most instructive localities found to illustrate the formation of peat under varying conditions.

WARBA

Locality 146.—A burned muskeg between mile posts 100 and 101 along the Great Northern railroad tracks northwest of Warba station. The dominant plants of the bog consist of sedges, cattails, bulrushes, and a few tamarack trees (mostly dead). Swamp ferns and heaths are common at the southeast end of the bog, and sphagnum is also present although most of it has been burned off. The peat is underlain by fine white sand. The deposit represents the built-up marshy shores of the lake, a remnant of which still occupies a portion of the bog.

An area of several square miles is included within this bog, including a lake of about 160 acres. The average thickness of the peat as indicated by test holes, is only about 4 feet. The peat is brown and fibrous.

The location of the test holes is as follows:

Hole 1—3,600 feet northwest of mile post 101 along Great Northern railroad; thickness 3½ feet. Brown sedge-peat.

Hole 2—2,600 feet northwest of mile post 101 along Great Northern railroad; thickness 4 feet. Brown sedge-peat.

Hole 3—2,000 feet northwest of mile post 101 along Great Northern railroad; thickness 6 feet. Fibrous, brown peat.

Hole 4—1,000 feet northwest of mile post 101 along Great Northern railroad; thickness 1½ feet. Very fibrous peat.

Hole 5—¼ mile southeast of mile post 101 along Great Northern railroad; thickness 3 feet. A little moss on top.

Analysis 112 (page 78) represents this deposit. The bog contains numerous small, low, sandy islands. If the area were well drained parts of it might be used for agricultural purposes, but the peat is of little value for fuel because of its shallow depth and undecomposed condition.

Locality 147.—An open heath-sedge bog, about 2 miles northwest of Warba. Sphagnum and heath shrubs, with a few scattered dead tamarack trees are the principal plants growing on the bog. The peat is underlain by black muck. The deposit is probably formed by the building up of the surface from a peat-filled lake. An open lake still exists at the south end of the bog.

The peat deposit covers several square miles, and the average thickness is approximately 8 feet. The maximum thickness indicated by test holes is 11 feet. The top 3 feet of the peat is fibrous and mossy. Well decomposed, brown sedge-peat occurs in the lower portion of the deposit, with several inches of greenish peat at the bottom. The peat near the surface is composed mostly of sphagnum remains; sedges and rushes constitute the middle layers, and pondweeds make up the greenish peat near the bottom.

The location of the test holes is as follows:

Hole 1—400 feet southeast of mile post 100; 1¾ miles northwest of Warba; thickness 7 feet. Fibrous top 2 feet.

Hole 2—Mile post 99½; thickness 11 feet. Decomposed below 3 feet. A little green peat at the bottom.

Hole 3—Mile post 99¼; thickness 7 feet. Decomposed below 3 feet. A little green peat at bottom.

Hole 4—Mile post 99; thickness 8 feet. Well decomposed below 3 feet. Top is mossy.

Hole 5—Mile post 98¾; thickness 7 feet. Sedges, reeds, and rushes.

Analysis 113 (page 78) shows the composition of the peat.

COHASSET

Locality 148.—Bog about ½ mile northwest of Cohasset along the Great Northern railroad. The deposit is of the built-up or high-moor type. The vegetation is chiefly sphagnum moss, heath shrubs, and sedges, with numerous spruce and tamarack trees. The peat is underlain by coarse sand.

The area of the bog is about 320 acres. The average thickness of the peat is approximately 9 feet, and the maximum 11 feet, as indicated by test holes. The peat is light brown in color, and of the fibrous variety. It is made up chiefly of sphagnum moss with remains of bulrushes, reed-grass, and cattails. Numerous logs and roots are imbedded in the peat throughout the deposit.

The location of the test holes is as follows:

Hole 1—At mile post 117½; thickness 7 feet. Mossy peat on top. Sedge-peat below.

Hole 2—At mile post 117¾; thickness 11 feet. Mossy peat on top. Sedge-peat below.

Hole 3—At mile post 118; thickness 4 feet. All moss peat.

Analysis 114 (page 78) represents this bog. While the peat is of good fuel value, the growth of spruce and other vegetation is so heavy that it would be expensive to clear the bog.

JACKSON COUNTY

The topography of Jackson County shows some rather striking features, namely the post-glacial valley of the Des Moines River, 100 to 150 feet deep, and a prominent moraine extending north and south through the center of the county. Most of the surface is, however, almost flat, and in consequence there are numerous lakes and marshes scattered over the area. The largest and best known of these is Heron Lake, which, according to Warren Upham,[79] occupies a portion of a buried pre-glacial river valley.

Mr. H. R. Leonard, county agricultural agent, reports that there is very little peat in the county notwithstanding the numerous lakes. Heron Lake contains a little peat along portions of its shore line, and peat is now rapidly forming throughout its area, which is invaded by a heavy growth of wild rice, cattails, and lake bulrushes. Concerning the small marshes, Winchell[80] reports the following localities as containing shallow peat deposits. None of these are of commercial importance, however, and some have completely disappeared with draining and plowing of the land.

Delnfield T. (104N., R. 36W.) SW¼ sec. 4.

Weimer T. Very small quantity. 6 inches thick.

Wisconsin T. (102N., R. 34W.) sec. 27.

Round Lake (shores) 4 to 5 acres of shallow peat associated with bog iron.

Heron Lake shore, sec. 14. 200 to 300 acres of peat about 2 feet thick.

[79] Warren Upham, Final Report, Geological and Natural History Survey of Minnesota 1:507. 1882.

[80] N. H. Winchell, Final Report, Geological and Natural History Survey of Minnesota 1:515. 1882.

There are other localities where small shallow peat deposits occur, but none of these contain peat in sufficient quantity to deserve special mention. Most of these wet tracts can be used for raising crops within 2 or 3 years after draining.

KANABEC COUNTY

There are no extensive deep peat deposits in Kanabec County although there are numerous swampy areas which are covered with shallow peat or muck. The total area of originally wet land in the county which requires, or did require, drainage, is given by the State Drainage Engineer as 42,000 acres.[81] Most of this area is not peat covered, but there are probably 15,000 acres in the county which contain shallow peat. Much of the land when properly drained could be used for agricultural purposes.

KANDIYOHI COUNTY

Kandiyohi County contains about 60 swamps, most of them small, but some attain an area of more than 1,000 acres. The swamps are nearly all located either in the northern row of townships, or in the southeast quarter of the county. There are many lakes in Kandiyohi County, and the majority of the swamps are situated around these lakes, especially in the southeast part of the county. Most of the swampy areas are covered with peat. These are shallow for the most part, but some contain peat up to 10 feet deep. The largest and deepest deposits are in Burbank and Colfax townships, in the northern part of the county, and in Fahlun, Elizabeth, Lake Lillian, and East Lake Lillian townships in the southeastern portion. Nearly all of the swamps are of the open sedge marsh type, and many are used for pasture, or for hay meadows. Comparatively few of the swamps lie next to any railroad, but there are 4 or 5 within 2 miles of a railroad. It is not probable that any of these areas can be utilized at present for fuel, but some may supply sedges and grasses for the manufacture of grass carpets and it is possible that some of the shallower marshes, when properly drained, may be used for agriculture.

KITTSON COUNTY

This county lies in the extreme northwest corner of Minnesota and is entirely within the area formerly covered by glacial Lake Agassiz.

The total area of the county is 1,111 square miles of which 73 square miles, or 6.6 per cent of the area is swamp land.[82] Most of these swamps are covered with peat. These deposits lie chiefly in the eastern and northeastern parts of the county, and this distribution is shown on the

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[81] Engineer's Report of Topographical and Drainage Survey Minnesota. 1906.

[82] Frank Leverett, and U. G. Purssell, *op. cit.* p. 43.

large map (Plate I) accompanying this report. The peat in these swamps is generally shallow, ranging from 2 to 6 feet. The average thickness is about 3½ feet. It has not been found practicable to manufacture peat fuel from deposits so shallow. It is quite probable, however, that when these swampy areas are drained much of the land will be available for agriculture.

KOOCHICHING COUNTY

There are approximately one million acres of wet or swamp lands in Koochiching County, and most of this area is covered with from 2 to 20 feet of peat. The average depth of the peat in the county is about 7 feet, and there are at least 750,000 acres of muskeg swamps over which the peat will average 7 feet thick. Koochiching, Beltrami, and St. Louis counties contain each at least one million acres of peat land.

The distribution of the peat deposits in the county is shown on the map on Plate III, in the pocket at the back of this report. It will be seen from an inspection of this map that most of the dry land of the county consists of narrow belts lying along stream courses. The muskeg swamps usually begin a few hundred yards back from the streams. The largest areas of dry land in the county occur along Rainy River, which forms the north boundary of the county. There are some morainic belts of sandy land, and also some old beach or shore deposits, which rise above the general level of the swamps in a few places and break their continuity, but aside from the comparatively small areas of land just mentioned, and larger areas in the eastern and southern portions, Koochiching County is a vast muskeg swamp.

The peat in these swamps is, in general, of an excellent quality for peat fuel. It has a uniform texture and composition, and the surfaces of the swamps possess sufficient slope (to the north) to render their drainage comparatively simple. There are several types of peat bogs in the county, but by far the commonest is a typical muskeg swamp, forested with tamarack, or spruce, or both. Within these great tamarack-spruce swamps are numerous open areas of typical heath bog. The third type of peat deposit found in the county is the open sedge-marsh. These are rare in this region, but a few small ones occur in the southern part of the county.

Nearly all of Koochiching County lies within the area formerly covered by the waters of glacial Lake Agassiz. The bottom of this lake was flat but not level and after the draining of the waters of the lake the topography of the newly exposed land was favorable to the formation of marshes and sloughs, with here and there a lake or pond filling some depression below the general flat surface. These conditions explain the formation of the vast unbroken swamp that now covers much of the area.

The peat deposits of Koochiching County are in general of the built-up or high-moor type. Only certain comparatively small parts of the swamp represent filled lakes, where the peat is unusually deep and of a different character from that which prevails in the greater part of the area. The depth and distribution of the peat in the western half of Koochiching County, where the most extensive swamps occur, is shown in Figure 6. Several characteristic relations already referred to are brought out clearly on this map. The occurrence of the deepest peat in isolated basins surrounded by successive zones of shallower peat suggests that these deeper portions represent filled lakes. The zonal arrangement of the peat deposits of different depths indicates built-up deposits on flat, but gently sloping surfaces, and the building up of the peat deposits above the levels of the old, filled lakes. The relation of the vegetation to the depth of the peat is clearly shown. In all cases where deep peat is indicated, the tamarack and spruce trees are small. As the peat becomes shallower, the size of the trees increases. In some of the deepest parts of the bogs there are no trees, and the area is covered with heaths.

There are a large number of drainage ditches already completed in Koochiching County, and hundreds of miles of additional ditches are projected. Mr. E. W. Kibbey, the engineer in charge of the drainage work in this county, has given much assistance, and supplied much valuable data in the course of the preparation of this report. Several thousand soundings were made in the swamps throughout the county under the direction of Mr. Kibbey, and the map shown in Figure 6 was constructed by him largely from this data.

A very large part of the swamp land in the county can probably be reclaimed for agricultural purposes when the drainage of the region is more complete. This is especially true in those localities where the peat is less than 6 feet thick (see Figure 6). Even on the land where the peat is more than 6 feet thick, experience has shown that certain crops can be successfully grown on the peat soil. (See descriptions of the Island and Meadowlands bogs in St. Louis County, pages 218 and 240.) The detailed descriptions which follow, with a few exceptions, include some of the peat deposits near the railroad.

INTERNATIONAL FALLS

Locality 126.—Muskeg swamp in secs. 19, 20, 21, and 22, T. 159N., R. 25W. along Branches 4 and 5 of Drainage Ditch 21; about 20 miles southwest of International Falls, and north of Loman. The vegetation consists of tamarack and spruce trees with sphagnum, heath shrubs, and sedges. The peat is underlain by sand and clay. The swamp covers an area of many square miles. The average thickness of the peat at

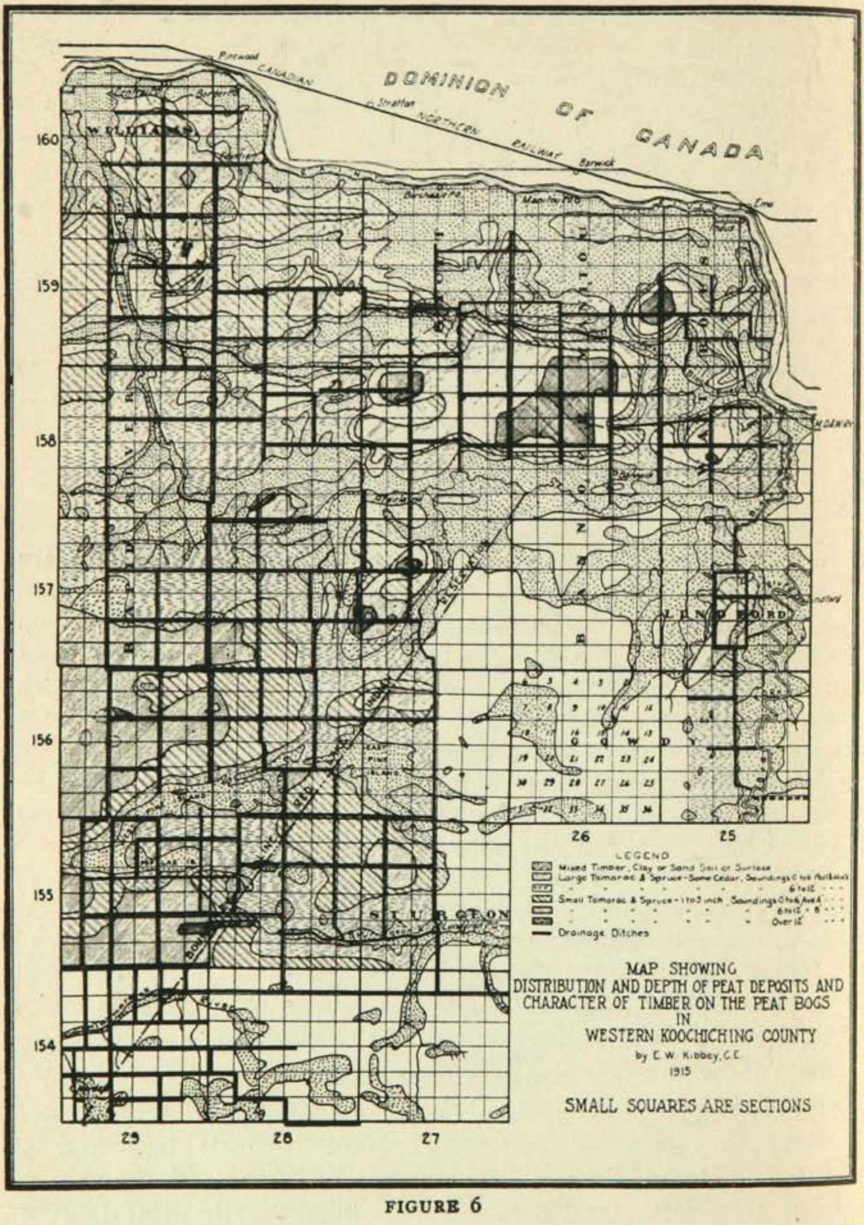
DOMINION OF CANADA
CANADIAN NORTHERN RAILWAY
160
159
158
157
156
155
154
29
28
27
26
25
LEGEND
Mixed Timber, Clay or Sand Soil at Surface
Drainage Ditches
MAP SHOWING
DISTRIBUTION AND DEPTH OF PEAT DEPOSITS AND
CHARACTER OF TIMBER ON THE PEAT BOGS
IN
WESTERN KOOCHICHING COUNTY
by E. W. Kibbey, C.E.
1915
SMALL SQUARES ARE SECTIONS

FIGURE 6

this locality is about 9 feet, with a maximum of more than 14 feet. The peat is brown, mossy on top, but well decomposed below, with considerable wood fibre in places. It is made up mostly of sphagnum and heath remains. Test holes were located every ¼ mile for 3 miles along the south line of sections 19, 20, 21, and 22 from east to west. Samples were collected every 2 feet from the top to the bottom of the peat from each of 12 holes, and all mixed in order to obtain an average.

Analysis 115 (page 78) shows the composition of this sample. Considerable clay from the bottom of several holes became mixed with the sample which renders the analysis of this peat untrustworthy. The true ash content of the peat is probably much lower than is indicated by this analysis.

Locality 126a.—This is another portion of the same swamp just described under Locality 126. The sample here was collected along Branches 4 and 5 of Ditch 21, on a north line across the east boundary of secs. 17, 20, 29, and 32, T. 159N., R. 25W.

Analysis 116 (page 78) represents an average of this sample.

MARGIE

Locality 168.—Tamarack-spruce swamp, 1¾ miles southwest of Margie along the Minnesota and International railroad. The vegetation consists of 3- to 6-inch tamarack and spruce trees, and a few cedars. There are also heath shrubs and swamp ferns. The peat is underlain by sand and clay. This is a part of the great Koochiching County swamp which covers hundreds of square miles. At this locality the average thickness of the peat is 5 feet, with a maximum of 7 feet. The peat is brown, fibrous, and undecomposed. It is made up chiefly of sedges with remains of bulrushes and reed-grass, and contains some buried wood. Test holes were located as follows:

Hole 1—At mile post 155 near margin of bog; thickness 1 foot.
Hole 2—¼ mile southwest of No. 1; thickness 4 feet.
Hole 3—¼ mile southwest of No. 2; thickness 7 feet.
Hole 4—¼ mile southwest of No. 3; thickness 4 feet.

Analysis 117 (page 78) shows the composition of the peat at this locality. A state ditch nearby extends parallel to the railroad for 8 miles. The dredge was at work on this ditch when the locality was visited, and it is planned to extend the ditch as far as Gemmell.

Locality 169.—Tamarack-spruce-cedar swamp, 2¾ miles southwest of Margie along the Minnesota and International railroad. This is a continuation of the swamp described under Locality 168. The vegetation here consists of tamarack, spruce, and cedar timber, with heath shrubs, swamp-willow, swamp birch, cotton-grass, and sphagnum. The peat is underlain by sand and clay.

At this locality the peat averages 5 feet thick, and the maximum thickness recorded by test holes is 8 feet. The peat is light brown, fibrous, and woody. The locations of the test holes are as follows:

Hole 1—At mile post 153¾; thickness 7 feet. Stratified, fibrous peat with 6 inches of moss on top.
Hole 2—At mile post 153½; thickness 8 feet.
Hole 3—At mile post 153¼; thickness 6 feet. Top 4 feet contains much wood.
Hole 4—At mile post 153; thickness 4 feet. Peat is full of wood and roots.
Hole 5—At mile post 152¾; thickness 1 foot. Mostly wood fibre.
Hole 6—At mile post 152½; thickness 1½ feet. Much wood in peat.
Hole 7—At mile post 152¼ near island; thickness 2 feet. Much wood in peat.

Analysis 118 (page 78) shows the composition of the peat at this locality.

Locality 170.—Tamarack-spruce-cedar swamp, 4¾ miles southwest of Margie along Minnesota and International railroad. This is also a continuation of the same swamp as that just described under localities 168 and 169. The peat in this portion of the swamp is only about 3 feet thick. It is of the same general character as in the other portions of the swamp just described.

The location of the test holes is as follows:

Hole 1—At mile post 152, 400 feet from margin; thickness 3 feet.
Hole 2—At mile post 151¾; thickness 2½ feet.
Hole 3—At mile post 151½; thickness 2⅓ feet. Top 6 inches is sphagnum peat.
Hole 4—At mile post 151¼; thickness 2½ feet. Top 12 inches is sphagnum peat.
Hole 5—At mile post 151; thickness 3 feet. Top 12 inches is sphagnum peat.
Hole 6—At mile post 150¾; thickness 1 foot. Large trees growing on bog.

Analysis 119 (page 78) shows the composition of the peat from these test holes. This part of the swamp is so shallow that after properly draining and clearing the area, the land could probably be used for agriculture.

Locality 171.—This is also a continuation of the same big swamp just described under preceding locality numbers. The peat here has an average thickness of only about 3 feet.

The location of the test holes is as follows:

Hole 1—At mile post 150½; thickness 1 foot.
Hole 2—At mile post 150¼; thickness 2 feet.
Hole 3—At mile post 150; thickness 3 feet. Firm, dark brown to black, fibrous peat, with much wood.
Hole 4—At mile post 149¾; thickness 5 feet. Top foot is sphagnum peat. Below is sedge peat with remains of heaths, cattails, bulrushes, and weeds.
Hole 5—At mile post 149½; thickness 1 foot. All sphagnum peat. Dense growth of trees and heaths.
Hole 6—At mile post 149¼; thickness 1 foot. All sphagnum peat. Dense growth of trees and heaths.
Hole 7—At mile post 149; end of swamp; thickness 1 foot. All sphagnum peat. Dense growth of trees and heaths.

Analysis 120 (page 78) represents this portion of the swamp. The preceding samples were taken along the ditch parallel to the railroad. The swamp extends back for miles on both sides of the railroad, and its general character throughout this region is the same as already described. The peat is too shallow for peat fuel or other uses, and contains too many roots and stumps to be easily removed. The growth of tamarack, spruce, and cedar timber is very dense over most of the area, and clearing would be expensive. On the other hand, when once cleared, the land could be used for agriculture, for the subsoil is good and the peat is shallow enough in places to be plowed into the soil with a deep tiller.

Locality 172.—This is a typical muskeg 8½ miles southwest of Margie along the Minnesota and International railroad, in secs. 2 and 11, T. 152N., R. 27W. The vegetation consists of tamaracks, spruce, sphagnum, and heath shrubs. The peat is underlain by white sand. The deposit at this locality occupies a long narrow depression between two low sandy ridges.

The area of the swamp is very large, but this locality represents a comparatively narrow arm. The average thickness of the peat as indicated by test holes is about 6 feet at this place, and the maximum thickness is 7 feet. The peat is light brown, well decomposed, and rather plastic. The top 1½ feet is composed entirely of sphagnum. Below the moss, the peat consists chiefly of the remains of sedges, grasses, bulrushes, reeds, and heaths.

The locations of the test holes are as follows:

Hole 1—500 feet from mile post 148 at south margin of bog; thickness 4 feet.
Hole 2—500 feet north of No. 1; thickness 7 feet.
Hole 3—500 feet north of No. 2, and 500 feet from north margin; thickness 5 feet.

Analysis 121 (page 78) represents this sample.

GEMMELL

Locality 173.—Bog 2¾ miles northwest of Gemmell along Minnesota and International railroad. This is another arm of the same big swamp as that described under Locality 172. The vegetation here consists of sphagnum moss, heath shrubs, swamp birch, swamp-willow, liverworts, and scattered dead tamarack trees. The peat is underlain by white sand, and the deposit occupies a rather narrow depression between two low sandy ridges. The bog is probably a burned muskeg.

There are about 400 acres in this portion of the swamp. The average thickness of the peat, which is dark brown and fibrous, is only 3 feet.

Samples were collected every foot from top to bottom of the peat from each of 4 holes and mixed together.

Hole 1—400 feet from north margin of bog, along railroad; thickness 2 feet.
Hole 2—1,000 feet south of No. 1; thickness 4 feet.

Hole 3—1,000 feet south of No. 2; thickness 3 feet.
Hole 4—1,000 feet south of No. 3; 200 feet from south margin; thickness 3 feet.

Analysis 122 (page 78) shows the composition of the peat as indicated by these samples. This muskeg has been completely drained, and the peat is unusually dry. The locality is of no value as a source of peat fuel.

Locality 174.—Tamarack-spruce swamp 1 mile northeast of Gemmell along Minnesota and International railroad. This represents another arm of a very large swamp, which covers many square miles. The vegetation here consists of tamarack, spruce, and cedar trees, with heath shrubs and cranberry vines. In the open spaces of the bog, swamp ferns, goldenrod, and grasses appear. The peat is underlain by sand and clay.

This arm of the swamp includes an area of about 4 square miles. The average thickness of the peat as indicated by test holes is about 3 feet, with a maximum thickness of 6 feet. The peat is light brown in color, poorly decomposed near the top, but softer below. It turns dark brown upon exposure to air. The peat is composed chiefly of sedges, grasses, and heaths, with the remains of bulrushes, cattails, and reed-grass near the bottom. It contains many decomposed twigs and branches of trees.

Samples were collected every 2 feet from top to bottom of the peat from each of these holes as follows:

Hole 1—At mile post 146½; thickness 1½ feet.
Hole 2—At mile post 146¼; thickness 3 feet.
Hole 3—At mile post 146; thickness 6 feet.
Hole 4—At mile post 145¾; thickness 4 feet.
Hole 5—At mile post 145½; thickness 1 foot.
Hole 6—At mile post 145¼; edge of bog; no peat.

Analysis 123 (page 78) shows the composition of the peat at this locality.

LITTLE FORK

Locality 198.—Shallow swamp 1¾ miles north of Little Fork along Minnesota and International railroad. The vegetation consists of large birch and tamarack trees with some spruce. The undergrowth consists of swamp birch, willow, laurel, and hazel brush. Small areas near the track, which have been burned, showed fire weed, thistles, and raspberries. Sedges and grasses also were noted. The peat is underlain by clay.

There are many square miles in this bog. The average thickness of the peat at the locality sampled is about 4 feet with a maximum of 7 feet. The peat is light brown in color, woody, dry, and poorly decomposed. It is made up chiefly of the remains of wood, with one thin layer of sedge-peat at a depth of about 4 feet.

Samples were collected every 2 feet from top to bottom from each of 4 holes as follows:

Hole 1—Mile post 186¼; ¾ mile north of south margin; thickness 6 inches.

Hole 2—¼ mile north along track; thickness 2 feet. Some sphagnum.

Hole 3—¼ mile north along track; thickness 5 feet. Small grove of spruce, 2- to 4-inch trees.

Hole 4—¼ mile north along track; thickness 7 feet. Plastic below 2 feet; well decomposed. Red, woody peat, 4 feet; sedges, reeds, etc. 1 foot; dark red, woody peat, 2 feet (bottom).

Analysis 124 (page 78) shows the composition of the peat at this locality. This portion of the large bog has been recently burned. The timber is dead, and there are numerous great tufts of moss, on which the ashes can still be seen. The sphagnum for the most part is dead and brown.

Locality 199.—Big muskeg swamp between little Fork and Nakoda, on the Minnesota and International railroad. This sample was taken from secs. 26 and 27, T. 69N., R. 25W. The muskeg swamp seems to have invaded a forest of coniferous trees at an early stage in its history, as is evidenced by the 2- to 4-foot layer of logs, cones, and spruce needles near the bottom of the peat. The vegetation consists chiefly of spruce and tamarack trees, heath shrubs, and sphagnum. The peat is underlain by clay.

The bog contains an area of many square miles. At this locality the average thickness of the peat, as shown by test holes, is approximately 11 feet. The upper 5 feet of the deposit consists of light brown, fibrous, rather fluid peat. Below 5 feet and extending to 9 feet, is a layer of red-brown peat, containing spruce needles. Below this depth the peat becomes soft, plastic, well decomposed, and shows stratification. The upper 3 feet consists of the remains of sedges, reeds, and cattails. Very little sphagnum was recognized in the peat. There is much wood mixed with the soft peat at the bottom of the deposit.

Samples were collected every 2 feet from the top to the bottom of the peat from each of 4 holes and mixed in a sample sack.

Hole 1—At mile post 187¼; thickness 8 feet. Fibrous on top; woody below.

Hole 2—At mile post 187½; thickness 10 feet. Top 7 feet is good sedge-peat. Moss has been burned off.

Hole 3—At mile post 187¾; thickness 12 feet. At 7 feet, a layer of cones, needles, and wood occurs.

Hole 4—At mile post 188; thickness 13 feet. At 7 feet, a layer of cones, needles, and wood occurs.

Analysis 125 (page 78) shows the composition of the peat from these samples. The railroad track between Nakoda and Little Fork extends across this peat swamp for at least 5 miles, and throughout this distance the peat shows remarkable uniformity in thickness and excellent fuel qualitites.

Locality 200.—Continuation of same muskeg swamp along Minnesota and International railroad between Little Fork and Nakoda as just described under preceding Locality 199. The vegetation of the swamp and the character of the peat here is essentially the same as in that portion of the swamp just described. The peat is underlain by clay, and the contact between the peat and clay is sharp. Imprints of reeds and other plants are well marked on the surface of the clay. The peat in this portion of the swamp is 12 to 13 feet thick. The upper 4 feet consist mainly of moss, followed by 2 or 3 feet of sedge-peat. Below this is a 2-foot layer of red-brown, wiry peat, composed mostly of needles of coniferous trees, with pieces of wood. Below this woody layer, the peat consists of the remains of sedges, cattails, and reeds.

Test holes were located as follows:

Hole 1—At mile post 188¼; thickness 13 feet. Typical muskeg. 2 feet of sphagnum moss.
Hole 2—At mile post 188½; thickness 12 feet.
Hole 3—At mile post 188¾; thickness 14 feet. Open sedge bog surrounded by muskeg.
Hole 4—At mile post 189; thickness 13 feet. Top 4 feet is moss peat.

Analysis 126 (page 78) shows the composition of this peat. Along this part of the swamp there are frequent changes in the vegetation growing on the bog, from scrub tamarack to open sedge areas, to spruce. The depth of the peat, however, is the same throughout, showing the independence of depth of peat and surface vegetation. The peat in this part of the swamp would make good fuel.

Locality 201.—Continuation of same muskeg swamp along Minnesota and International railroad between Little Fork and Nakoda, just described under localities 199 and 200. In this part of the swamp, the peat for a depth of 7 feet consists of light-brown, fibrous material, below which occurs red-brown, wiry, firm, undecomposed peat, underlain by a layer of decomposed peat containing pieces of wood. The upper 7 feet is made up chiefly of the remains of moss, sedges and cattails. Below this the peat consists largely of the remains of coniferous trees with a groundmass of spruce needles. The thickness of the peat in this part of the swamp is from 13 to 14 feet. The locations of the test holes are as follows:

Hole 1—At mile post 189¼; at east ditch; thickness 14 feet.
Hole 2—At mile post 189½; thickness 12 feet.
Hole 3—At mile post 189¾; thickness 11 feet.
Hole 4—At mile post 190; thickness 13 feet.

Analysis 127 (page 78) shows the composition of the peat in this part of the swamp. There are few trees growing in the swamp at this locality, and the area is very well drained by the ditch along the railroad, and by an intersecting east-west ditch. The swamp here could be cleared at a comparatively small expense.

Locality 202.—Continuation of same muskeg swamp along Minnesota and International railroad between Little Fork and Nakoda as just described under preceding localities, 199, 200, and 201. This part of the area has been burned. There are open spaces covered by sedges and heaths.

The peat for a mile along the track has a uniform thickness of 13 to 14 feet. The upper half of the deposit is red-brown, fibrous, undecomposed peat, below which occurs red-brown, soft, fibrous, rather plastic material. The top 2 feet is made up chiefly of sphagnum moss. From 2 to 8 feet, sedge remains predominate. Below 8 feet, there is a zone of peat composed of the stumps and remains of coniferous trees, and leaves of heath shrubs.

Samples were taken from top to bottom of the deposit from each of 4 holes as follows:

Hole 1—At mile post 190¼, thickness 13 feet.
Hole 2—At mile post 190½; thickness 12 feet.
Hole 3—At mile post 190¾; thickness 14 feet.
Hole 4—At mile post 191; thickness 12 feet.

Analysis 128 (page 78) shows composition of the average of these samples.

Locality 203.—This is a continuation of same muskeg swamp along Minnesota and International railroad between Little Fork and Nakoda, as just described under localities 199, 200, 201, and 202. The vegetation in this portion of the swamp consists of 2- to 4-inch tamarack trees, some small spruce trees, heath shrubs, sedges, grasses, and sphagnum moss. The average thickness of the peat in this portion of the swamp is 10 feet. The maximum thickness is about 12 feet. Test holes were put down as follows:

Hole 1—At mile post 191¼; thickness 12 feet.
Hole 2—At mile post 191½; thickness 12 feet.
Hole 3—At mile post 191¾; thickness 11 feet.
Hole 4—At mile post 192; thickness 8 feet. Near an arm of dry land.
Hole 5—At mile post 192¼; thickness 10 feet.
Hole 6—At mile post 192½; thickness 10 feet.
Hole 7—At mile post 192¾; thickness 11 feet.
Hole 8—At mile post 193; thickness 6 feet. 500 feet from edge of bog.

Analysis 129 (page 78) shows composition of the peat at this place. A comparison of the analyses of this and the preceding 4 samples will show a uniformity in the composition of the peat in this big swamp.

WISNER

Locality 204.—Muskeg along Minnesota and International railroad, northeast of Wisner in secs. 35 and 36, T. 67N., R. 26W. The vegetation of this swamp consists of sphagnum and polytrichiem moss, heath shrubs, sedges, and a few tamaracks, most of which are dead. The peat is underlain by sand.

Test holes showed the average thickness about 13 feet. The top 3 feet of the deposit consists of mossy, light brown peat, below which is 3 feet of brown, fibrous peat. From 6 to 9 feet, the peat is red-brown in color, and somewhat plastic, with abundant woody fibre. From 9 to 14 feet the peat is brown, fibrous, and rather firm.

Samples were collected every 2 feet in depth, from top to bottom of the peat, from each of 4 holes, as follows:

Hole 1—At mile post 179; ¼ mile southwest of margin; thickness 6 feet. Red-brown, woody peat.
Hole 2—At mile post 178¾; thickness 11 feet.
Hole 3—At mile post 178½; thickness 12 feet.
Hole 4—At mile post 178¼; thickness 14 feet. The surface vegetation here is varied.

Analysis 130 (page 78) represents this portion of the bog. The trees are small and scattered, and the surface of the bog could be cheaply cleared. This locality is favorable to the development of a plant to manufacture machine peat. The peat is of good quality for fuel.

Locality 205.—This is a continuation of the same muskeg as that just described under Locality 204. This portion of the swamp lies about 2 miles northeast of Wisner along the Minnesota and International railroad. The vegetation here is similar to that just described under the preceding locality. The peat is underlain by white clay.

The peat in this part of the bog has an average thickness of 8 feet, and a maximum thickness of 13 feet, where sampled. The peat gradually changes from light brown, fibrous material in the upper portion, to red-brown, plastic material below. At the north end of the line of test holes, the peat consists of mossy material on top, underlain by sedge remains containing twigs. At the south end of the line of test holes included in this sample, there is very little moss peat, and sedges comprise the chief constituent. The location of the test holes is as follows:

Hole 1—At mile post 178; thickness 13 feet. Typical tamarack muskeg.
Hole 2—At mile post 177¾; thickness 11 feet. Typical tamarack muskeg.
Hole 3—At mile post 177½; thickness 7 feet. Trees are larger here, and spruce, alders, and willows appear.
Hole 4—At mile post 177¼; thickness 3 feet.

Analysis 131 (page 78) shows the composition of the peat in this part of the swamp.

Locality 205a.—This is also a continuation of the same muskeg as that just described under localities 204 and 205. Test holes for this sample were started 1¼ miles northeast of Wisner, and continued along a line extending southward along the Minnesota and International railroad to a point ¼ of a mile northeast of Wisner. The peat here is shallow, the thickness averaging only about 2 feet. The vegetation consists of large spruce trees (8 inches in diameter), birch, poplar, heath shrubs (Labrador tea), cranberry vines, and a little sphagnum. This area has been burned in former years. The hardwood vegetation forms a zone around the edge of the large muskeg just described in the preceding localities. The peat is dark to red-brown, well decomposed, and contains much wood fibre.

Samples were collected from the top to the bottom of the peat from each of 4 holes as follows:

Hole 1—At mile post 187; thickness 3 feet.
Hole 2—At mile post 186¾; thickness 2 feet. Hardwood trees.
Hole 3—At mile post 186½; thickness 2 feet. Burned area.
Hole 4—At mile post 186¼; thickness 2 feet.

Analysis 132 (page 78) represents the average of these samples. This area, if cleared and drained, could probably be used for agricultural purposes. The peat is too shallow to be used for peat fuel.

Locality 206.—Muskeg swamp ¼ mile southwest of Wisner along the Minnesota and International railroad. Wisner lies on a point of higher land projecting into a very large muskeg, and is surrounded on three sides by peat bog. The vegetation here consists chiefly of scrub tamarack and spruce not more than 4 feet high. Heath shrubs are prominent; calmadaphne and andromeda predominate. There is no Labrador tea, which is the dominant heath in the swamp north of Wisner. Sphagnum moss and sedges also are prominent. The peat is underlain by coarse sand.

This swamp has an area of many square miles. The average thickness of the peat as indicated by the test holes is 7 to 8 feet. The upper part of the deposit is yellowish brown, mossy peat, which changes to dark brown, fibrous peat below, with 1 foot of thoroughly decomposed red-brown peat containing woody fibre at the bottom. The top 2 or 3 feet of the deposit is composed of sphagnum. The remainder consists of the remains of sedges, cattails, and reeds, with pieces of wood.

Samples were collected every 2 feet from the top to the bottom of the peat, from each of 3 holes located as follows:

Hole 1—At mile post 175½; thickness 6 feet.
Hole 2—At mile post 175⅜; thickness 8 feet. Brown, decomposed sedge-peat.
Hole 3—At mile post 175¼; thickness 7 feet.

Analysis 133 (page 78) represents the average of these samples.

Locality 207.—This is another part of the same big muskeg described in the preceding locality. The vegetation here consists of scrub tamarack, spruce, heath shrubs, sphagnum, sedges, and cotton-grass. The peat is underlain by sand. The average thickness of the peat in this part of the swamp is about 6½ feet. It is brown, rather plastic, and somewhat decomposed. It is made up of sphagnum near the surface, below which remains of sedges, grass, twigs, and woody fibre predominate. Test holes were located as follows:

Hole 1—At mile post 174¾; thickness 6 feet.
Hole 2—At mile post 174½; thickness 8 feet.
Hole 3—At mile post 174¼; thickness 7 feet.
Hole 4—At mile post 174; thickness 6 feet.
Hole 5—At mile post 173¾; thickness 4 feet.

Analysis 134 (page 78) shows the composition of the peat in this part of the swamp. A large drainage ditch was under construction at the time of investigating this locality, and although the ditch was not completed the peat was already well drained for several feet in depth. A mile or so northeast, where no ditch had been excavated, the surface of the swamp was covered with water.

BIG FALLS

Locality 208.—Muskeg 4 miles southwest of Big Falls along the Minnesota and International railroad. The character of the vegetation growing on this bog varies with the depth of the peat. In the shallow portions of the bog there is a rather dense growth of 4- to 6-inch tamaracks with some 2- to 3-inch cedars, swamp birch, heath shrubs, sphagnum and polytrichiem moss. In the deeper portions of the bog, the trees are much smaller, and sedges and cotton-grass appear. The peat is underlain by sandy clay. The deposit occupies a shallow depression between two sandy ridges of glacial drift.

This swamp comprises an area of many square miles. The average thickness of the peat, as indicated by the test holes, is about 10 feet. The locations of the test holes are as follows:

Hole 1—At mile post 161¼; ¼ mile from south margin; thickness 6 feet.
Hole 2—At mile post 161½; thickness 10 feet.
Hole 3—At mile post 161¾; thickness 10 feet.
Hole 4—At mile post 162; thickness 10 feet.

Analysis 135 (page 78) represents the composition of this peat. This part of the swamp is well drained. Since drainage, the peat has shrunk and packed firmly so it was difficult to push the sampling instrument down through the peat.

Locality 209.—This is a part of the same swamp described under Locality 208. The samples here described were taken along the Minnesota and International railroad 2 to 3 miles south of Big Falls. This is a tamarack-spruce-cedar swamp. The vegetation is very complex in this portion of the swamp, and varies greatly within short distances, partly due to the fact that portions of the swamp have been burned. The peat is underlain by sandy clay.

The swamp occupies an area of many square miles. Where sampled the average thickness of the peat is 7 feet, and the maximum thickness 8 feet. The upper 3 feet consists of light brown, fibrous, firm, stratified peat. Below this is a 2-foot layer of less fibrous, brown peat, somewhat plastic, underlain by 2 feet of decomposed, red-brown, woody peat. Most of the deposit is composed of parts of sedges, reeds, and cattails. There is a layer of sphagnum moss on top and of wood fibre at the bottom. The location of the test holes is as follows:

Hole 1—At mile post 162¼; thickness 8 feet. Tamarack zone.
Hole 2—At mile post 162½; thickness 6 feet. This place has recently been burned.
Hole 3—At mile post 162¾; thickness 7 feet. Cedar zone.
Hole 4—At mile post 163; thickness 7 feet. Peat is drained to depth of 6 feet. Tamaracks are dead.

Analysis 136 (page 78) represents this portion of the swamp. Many logs, stumps, and roots of trees are scattered over the surface of the swamp. The timber growth is dense in places, and clearing would be expensive. The location is not favorable for the development of a fuel plant.

Locality 210.—This is part of the swamp described under localities 208 and 209. The samples from this locality were taken from 1 to 2 miles south of Big Falls along the Minnesota and International railroad. The vegetation here consists of dead tamaracks, "red-top" grass, fireweed, swamp birch, swamp laurel, sedges, cotton-grass, a little moss, and a few alders. The peat is underlain by sandy clay. The average thickness of the peat here is only 4 feet, and it consists of light brown, fibrous to spongy material, composed chiefly of sedges, reeds, cattails, moss, and twigs. The locations of the samples are as follows:

Hole 1—At mile post 163¼; thickness 6 feet.
Hole 2—At mile post 163½; thickness 4 feet.
Hole 3—At mile post 163¾; thickness 4 feet.
Hole 4—At mile post 164; thickness 3 feet.

Analysis 137 (page 78) represents this portion of the swamp.

LAC QUI PARLE COUNTY

There is no peat in Lac qui Parle County.

LAKE COUNTY

Lake County is one of the most inaccessible counties in northern Minnesota and a large part of its area is still a wilderness. The only railroads in the county are in the extreme southern corner, and along the north shore of Lake Superior. There are in Lake County 190,200 acres of swamp lands.[83] Not all of this area is covered with peat, but most of the swamps in the county (about 150,000 acres) contain peat. Most of the swamps lie in the west central and northwestern parts of the county. None of these swamps are large as compared with those of St. Louis, Koochiching and Beltrami counties, but there are many which have an area of 3 or 4 square miles. Many of the Lake County swamps, especially in the central part of the county, occur along, and parallel to, lines of drainage. The prevailing direction of these swamps is northeast-southwest. In T. 58N., and T. 59N., R. 11W. are the largest unbroken swamps in the county. Other larger swamps are found in T. 59N., R. 7W.; T. 59N., R. 8W.; and T. 58N., R. 9W.

Nearly all of the Lake County swamps are typical muskegs, and they are usually timbered with growths of scrub tamarack and spruce so characteristic of all the muskegs of northern Minnesota. It is not probable that this peat will be utilized for many years, except, perhaps along the Duluth and Iron Range railroad in the southwest corner of the state, where the tracks lie close to several small deposits of good fuel peat. The following descriptions of some of these bogs near the railroad will give a better idea of the character and quality of the peat.

HIGHLAND

Locality 211.—Typical muskeg 1 mile north of Highland along the Duluth and Iron Range railroad. The vegetation consists of tamarack and spruce trees, heath shrubs, sphagnum and polytrichiem moss, liverworts, and a few sedges. The deposit represents a peat-filled lake which has been built up above the old water level by successive layers of sedges and sphagnum peat. The area comprises about 80 acres. The peat is very deep, and the bottom of the deposit can not be reached with a 20-foot sounding rod. The upper 8 feet of the deposit is dark brown, rather plastic, thoroughly decomposed sphagnum and sedge-peat. From 8 to 14 feet, the peat is straw-colored, compact, and fibrous. From 14 to 20 feet, it is greenish, soft, plastic pond peat. To a depth of 14 feet, the peat is made up chiefly of sphagnum and sedge remains. Below 14 feet it consists of the remains of pondweeds and other aquatic plants. Samples were collected every 2 feet from the top to a depth of 20 feet, from each of three holes as follows:

Hole 1—200 feet north of south margin along Duluth and Iron Range railroad; thickness 20+ feet. Only 14 feet of fuel peat.
Hole 2—200 feet north of No. 1; thickness 20+ feet. Only 14 feet of fuel peat.
Hole 3—200 feet north of No. 2 (200 feet south of north margin); thickness 6 feet.

Analysis 138 (page 78) represents the average of these samples.

[83] George A. Ralph, *op. cit.*

Locality 212.—Cedar swamp 1¼ miles southeast of Highland along the Duluth and Iron Range railroad. Cedar trees 2 to 6 inches in diameter, hazel brush, fireweed, goldenrod, sphagnum and polytrichiem moss constitute the dominant vegetation on the bog. The area contains about 300 acres. The average thickness of the peat as indicated by test holes is approximately 5 feet. The upper 2 feet of peat is firm, woody, and of a red-brown color. Below 2 feet in depth fibrous, brown sedge-peat occurs. Near the bottom of the deposit the peat is of the greenish pond variety. Remains of sedges and cattails predominate in the upper portion of the bog, and pondweeds and aquatic plants in the lower portion.

The location of the test holes is as follows:

Hole 1—500 feet west of east margin of bog. 1,500 feet west of railroad tracks at a point 1¼ miles southeast of Highland, along track; thickness 5 feet.
Hole 2—500 feet west of No. 1; thickness 6 feet.
Hole 3—500 feet south of No. 2; thickness 6 feet.

Analysis 139 (page 78) shows the composition of this peat. This bog and the one described under Locality 211 just preceding, are typical of the two general types of bogs occurring in western Lake County. They are all muskegs or cedar swamps. In addition to the localities described above, the following soundings of the peat bogs near Highland were supplied by Mr. W. A. Clark, chief engineer for the Duluth and Iron Range Railroad Company.

The following localities are all close to Highland station, which is at mile post 41.3 on the Duluth and Iron Range railroad.

5 miles north of mile post 39. Soundings; 9 feet of peat.
3 miles south of mile post 41. Soundings; 10 feet of peat.
250 feet south of mile post 41. Soundings; 30 feet of peat.
5 miles north of mile post 41. Soundings; 9 feet of peat.
46 miles north of mile post 42. Soundings; 9 feet of peat.

An unusual peat bog occurs 1 mile southeast of Highland station along the Duluth and Iron Range railroad. The railroad has cut through a low hill on the top of which there is a muskeg swamp, containing peat 12 feet deep. The railroad cut is deep so that the top of the rails are below the bottom of the peat exposed in the sides of the cut. The cut has exposed a perfect section of this rather deep peat bog and the contacts between the different layers of peat which make up the deposit may be clearly seen. The stratification of the peat is plainly shown. The section is as follows:

Top 4 feet; red-brown, woody, moss peat.
2 feet light brown, stratified, decomposed peat containing remains of cattails, sedges, and reed-grass.
2 feet black, well decomposed, fine grained peat, containing remains of sedges and reeds, with many twigs.

3 feet of soft, fine grained, plastic, greenish, pond peat.
Clay bottom.

LE SUEUR COUNTY

There are no large peat bogs in Le Sueur County, but a number of small meadows and marshes occur there, some of which contain shallow deposits of peat, and a few contain peat 6 or 8 feet deep. The county lies south of the southern limit of muskeg swamps. The peat bogs are all open sedge-grass meadows, and most of them are used for pasture or for hay meadows. A second type of peat bog is found along the valley of the Minnesota River, which forms the western boundary of the county. These river-plain peat deposits, like most others of the type, are too silty to be utilized for fuel, and are not fibrous enough for peat litter or packing.

The meadow peat bogs are very similar to those found in Blue Earth County, which were described in the foregoing pages. The Le Sueur County bogs, however, are not nearly so numerous nor as deep, as those in Blue Earth County.

LINCOLN COUNTY

There are no peat deposits in Lincoln County.

LYON COUNTY

Most of the poorly drained land in Lyon County is in the southwestern corner, on the upland plain, and lies at an elevation of about 1,700 to 1,750 feet above sea level. This region contains numerous lakes. The surface slopes from this elevated plain northeastward to the Minnesota River, and while the slope is not steep, it is nevertheless sufficient to enable the streams to erode considerable channels between the Coteau uplands and the low flat plain along the river. Hence the central portion of Lyon County, where the slope is steepest, contains no lakes or marshes. The northeast part of the county forms the south edge of the flat lowland, which extends from there to the Minnesota River, and contains numerous wet, poorly drained areas, although the depressions are not usually deep enough to become lakes. There are no peat deposits of commercial value in the county. Some of the marshy areas are covered with a few feet of muck, which, if properly drained, could be utilized for farm land.

McLEOD COUNTY

There are no peat deposits of commercial value in McLeod County.

MAHNOMEN COUNTY

There is very little swamp land in Mahnomen County, and the few small peat deposits are shallow. These occur chiefly in the eastern part of the county where the topography is morainic.

MARSHALL COUNTY

Marshall County lies entirely within the limits of glacial Lake Agassiz, and the surface of the land throughout the county is quite flat. Consequently, much of the area is poorly drained, and large swamps, or marshes, exist. These swamps lie chiefly in the northeast quarter of the county, although there are some swamps in the southern portion. The largest of the southern swamps lie between old lake beaches, between Viking and Anita. The largest of the northern swamps lie east and west of Thief Lake. The size and distribution of these swamps may be seen on the large map (Plate I) accompanying this report.

The total area of swamp land in Marshall County is about 183 square miles, 10.2 per cent of the total area of the county. Most of this swamp land is covered with shallow deposits of peat, the average thickness being about 3 feet. There are also thousands of acres of land in the county which were originally swampy, but which have recently been drained. These drained lands are often covered with a few inches of peat, but the thickness is insufficient to warrant the classification of these areas as peat swamps.

Nearly all of the peat deposits are of the open, sedge-marsh type. The only muskegs in the county are in the extreme northeast corner, east of Thief Lake. A large part of the land between the drained bed of Mud Lake and the town of Grygla has recently been drained and hence is not shown on the map (Plate I) as peat swamp. This land, however, has a shallow peat cover from 1 to 2 feet thick over many square miles. At the time the locality was last visited (August 1915), considerable areas of this newly drained land had been plowed, and crops of flax, barley, and other grains were growing on it.

The following descriptions, which represent typical peat areas of this region, show in detail the character of these shallow marshes.

HOLT

Locality 135.—Bog 9 miles northeast of Holt, on the western shore of Mud Lake (now drained) along section line between secs. 23 and 26. This is an open, treeless, sedge-grass marsh. Sedges, grasses, reeds, cattails, foxtail, thistles, and many other plants not typical of marshes, were observed. The peat is underlain by lake-washed, glacial till, and the area was formerly covered by Lake Agassiz. The peat represents a built-up deposit on a wet, flat, undrained surface, which was probably inundated for a part of each year, but which is not a permanent lake.

The area here described is a part of an immense marsh containing many square miles around the old bed of Mud Lake. The average thickness of the peat is about 3½ feet. It consists of dark brown, firm, stratified, flaky peat which is very fibrous near the surface. It is composed chiefly of sedges, grasses, cattails, and reed-grass. There is practically no moss in the peat. Samples were gathered from the freshly exposed peat in the sides of a drainage ditch at numerous places, and mixed.

Analysis 140 (page 79) represents this sample. This part of the marsh is typical of 20 or 30 square miles in this region. The marsh has recently been reclaimed by a system of large ditches, constructed under the supervision of Mr. William R. Hoag, chief engineer of the drainage work in the district. The land will all be farmed eventually. The peat is probably too shallow for a first-class peat fuel plant, and is unsuited to the manufacture of peat litter. This is the western edge of what was one of the largest open sedge marshes in the northwest. Figure A (Plate XXVIII) is a view looking along the main ditch through this marsh.

Locality 136.—This sample was taken from the corner of secs. 13, 18, 19, and 24, T. 156N., R. 40 and 41W., along Main Judicial Ditch 11. This is an open, treeless, sedge-grass marsh similar to that described under Locality 135. Sedges, grasses, foxtail, mustard, thistles, and many weeds are found growing on this marsh. Many of these plants have appeared since the area was burned. The peat is underlain by yellowish, pebbly lake-washed, glacial till. The area was formerly covered by glacial Lake Agassiz. The peat has been built up on a flat, undrained surface by successive layers of plant remains.

The marsh here is only part of an immense marshy tract covering many square miles in this region. The average thickness of the peat is only 2½ feet. It consists of dark brown, firm, fibrous, stratified peat, and is made up chiefly of sedges, grasses, reed-grass and cattails. Samples were gathered from the sides of the drainage ditch from the top to the bottom of the deposit and mixed.

Analysis 141 (page 79) represents the average of these samples. This marsh is similar in every respect to the one described under Locality 135, and is typical of an area of 25 or 30 square miles. The land will probably all be used for agricultural purposes at some time in the future. Crops of flax and barley are already growing on parts of the drained marsh. Figure B (Plate XXVIII) shows a field of barley nearby growing on peat 3 feet deep.

MIDDLE RIVER

Locality 178.—Marsh along Great Northern railroad between Middle River and Strathcona. Portions of the marsh are being farmed and hay was being cut at the time of investigation. The natural vegetation consists chiefly of sedges, grasses, bulrushes, goldenrod, and a few scattered tamarack trees now dead. The peat is underlain by lake-washed till, sand, and gravel. The entire area lies within the former limits of glacial Lake Agassiz and remnants of several old beaches occur as sand ridges in the marsh. (See the map on Plate I.)

The area of this marsh is at least 50 square miles. The average thickness of the peat at this locality is only 1 foot. This consists of brown fibrous peat which is dry and caked, and is composed chiefly of the remains of sedges, grasses, reeds, and bulrushes. The sampling was begun 2 miles north of Middle River and continued to within 1½ miles of Strathcona along the Great Northern railroad tracks. Results of sampling are as follows:

Hole 1—At mile post 43¾; thickness 2½ feet. All sedge-peat.
Hole 2—At mile post 44¼ (mile post 44 is on an island); thickness 2 feet.
Hole 3—At mile post 44¾ (mile post 44½ is on an island); thickness 1½ feet. Sedges and reed-grass.
Hole 4—At mile post 45¼ (mile post 45 is on an island); thickness 1 foot.
Hole 5—At mile post 45¾ (mile post 45½ is on an island); thickness 1 foot. Hardwood trees, brush, swamp birch, heath shrubs, dead tamarack.
Hole 6—At mile post 46¼ (mile post 46 is on an island); thickness 1 foot. Goldenrod and grass.

Analysis 142 (page 79) represents this portion of the marsh. There are many small narrow islands throughout this marsh, some of which represent old beaches or shore lines of glacial Lake Agassiz. Farms are located on these islands of dry ground, and the adjoining portions of the marsh are used for pastures or for hay meadows. A few grain fields were observed in the marsh, but the crops were poor.

STRATHCONA

Locality 179.—This is the north part of the same marsh described under Locality 178. The average thickness of the peat here is 2 feet, and test holes indicate a maximum thickness of 3 feet. The peat is light brown, dry, and spongy, and is composed mostly of the remains of sedges, grass, and reeds. Samples were taken from test holes along the Great Northern railroad in secs. 2, 3, 10, 11, T. 158N., R. 43W. The location of test holes is as follows:

Hole 1—At mile post 47¼; thickness 2 feet.
Hole 2—At mile post 47½; thickness 3 feet.
Hole 3—At mile post 48; thickness 3 feet.
Hole 4—At mile post 48¼; 1½ feet. Thickness here is variable.
Hole 5—At mile post 48½; thickness 2 feet.
Hole 6—At mile post 48¾; thickness 2 feet.

Analysis 143 (page 79) represents average of these samples. The deepest peat in this marsh lies between mile posts 48 and 48¾ along the Great Northern railroad. The marsh has been burned.

MARTIN COUNTY

Martin County contains no peat deposits of commercial value. There are only a few marshy areas of noteworthy size in the county, and while some of these contain shallow peaty deposits, they are too silty to be of use for peat fuel, or too shallow to be profitably worked for the peat. It may be possible to utilize these wet areas, after they are properly drained, for agricultural purposes.

The largest marshy tracts in the county lie in the vicinity of Fairmont, the county seat. The exact locations are as follows: Fairmont Township (T. 102N., R. 30W.); sections 3, 10, 11, 14, 23, 26, and 28. These areas all contain some marshy land. Rolling Green Township (T. 102N., R. 31W.); sections 27, 29, 30, 32, 33, and 34. Pleasant Prairie Township (T. 102N., R. 31W.); sections 9, 10, 15, 16, and 21 contain small, shallow marshes. Soundings in sections 29 and 30, Rolling Green Township, near Pierce Lake, showed only six inches of peat, the material below that depth being a black, sandy muck. All of the above land is either drained or will be in the near future, and large ditches for this purpose were under construction at the time of visit.

MEEKER COUNTY

There are numerous peat swamps and marshes in Meeker County, but none of these are large or important in comparison with the great muskegs which occur in the counties to the north. There are about 30 swamps in the county containing from 100 to 640 acres, and most of these are peat covered. The majority lie in a broad east-west belt, just south of the central portion of the county. Acton, Litchfield, Ellsworth, and Collinwood townships contain most of these peaty areas.

The bogs are not timbered, but they belong, for the most part, to the open sedge-marsh type. There are, however, some small tamarack swamps. The peat is generally shallow, although in a few places it attains a depth of 8 to 10 feet. Many of the bogs occur around the shores of existing lakes with which this portion of the county is dotted. Only a few of these peat bogs occur along the railroad, and it is unlikely that they will prove of value as a source of peat.

MILLE LACS COUNTY

There are 34,000 acres of swamp land in Mille Lacs County. Most of this swamp land lies in the northern part of the county, south of Mille Lacs Lake, and has a peat covering. There are numerous smaller swamps scattered throughout the county, especially between Onamia and Milaca. Along the Minneapolis, St. Paul, and Sault Ste. Marie railroad, which crosses the county south of Mille Lacs Lake, there are many peat bogs both of the muskeg and sedge-marsh types. The muskegs predominate, and some of these contain peat deposits of considerable depth. Large areas in this region have been burned, and the peat destroyed. The following description of a typical bog near Wahkon shows the character of the peat in this region.

WAHKON

Locality 225.—Swamp beginning ¼ mile east of Wahkon station on the Soo railroad, and extending about ¾ mile eastward along the railroad tracks. The swamp has been burned and the original vegetation has been somewhat altered. Sedges, heath shrubs, small poplar trees, polytrichiem moss, and fireweed were noted. The peat is underlain by white sandy clay.

The area examined includes about 360 acres. The average thickness of the peat within this area is approximately 5 feet. Test holes indicated a maximum thickness of 8 feet. The peat is brown, firm, dry, and spongy or fibrous. The upper 5 feet consists of the remains of sedges, reeds, cattails, heath shrubs, and contains many stumps and pieces of wood. Below 5 feet in depth the peat is composed largely of sphagnum. Samples were collected every 2 feet from the top to the bottom of the peat, from each of 3 holes located as follows:

Hole 1—¼ mile west of east margin of bog; thickness 5 feet.
Hole 2—¼ mile west of No. 1; thickness 6 feet.
Hole 3—¼ mile west of No. 2; thickness 8 feet.

Analysis 144 (page 79) represents average of these samples. The deposit contains good fuel peat. The surface is rather open and could easily be cleared.

MORRISON COUNTY

Morrison County contains about 20,000 acres of swamp land, most of which is covered with peat. These peat bogs are of various types. In the northern portion of the county, and especially in the northwest portion, tamarack and spruce swamps predominate. In the southern part of the county, open, sedge-marshes and meadows are the principal types. There is no line of division, however, between these types, and examples of both kinds of bog are scattered throughout the county.

Some of the most extensive swamps, and the deepest peat deposits in the county, occur in the region traversed by the Northern Pacific railroad between Little Falls and Staples. Swamps of especially large area occur at or near Lincoln, Cushing, Randall, and Darling, all stations of the Northern Pacific railroad in the northwestern part of Morrison County. Other bogs of importance, mostly open marshes, are situated along the Minneapolis, St. Paul, and Sault Ste. Marie railroad in the southeastern part of the county, especially near Vawter and Pierz. Muskeg swamps also occur around Hillman. A description of the Hillman swamp is given below.

HILLMAN

Locality 227.—Bog 3 miles west of Hillman along Soo railroad. This is probably burned muskeg which has reverted to a marsh covered with sedges, grasses, goldenrod, hazel bushes, moss, and a few burned tamaracks. The peat is underlain by black clay. The bog contains an area of about 100 acres, and the thickness of the peat ranges from 2 to 5 feet, with an average of about 3½ feet. The peat is brown, firm, fibrous, and rather gritty, and shows evidence of burning near the surface. It is composed chiefly of sedge and grass remains with a layer of moss peat at a depth of 3 feet below the surface.

Samples were taken every 2 feet from the top to the bottom of the peat from each of 5 holes as follows:

Hole 1—500 feet west of east margin of marsh, along track; thickness 2 feet.
Hole 2—500 feet west of No. 1; thickness 3 feet.
Hole 3—500 feet west of No. 2; thickness 4 feet.
Hole 4—500 feet west of No. 3; thickness 5 feet.
Hole 5—500 feet west of No. 4 (500 feet from west margin); thickness 2 feet.

Analysis 145 (page 79) shows the composition of this peat.

MOWER COUNTY

Mower County, which lies east of Freeborn County, and the southern boundary of which forms a part of the Minnesota-Iowa state line, is almost the same in area as Freeborn, consisting of twenty townships. It lies on one of the highest divides in southern Minnesota.

There are no peat deposits in Mower County. Winchell mentions a bed of peat eighteen inches thick along Horn Creek, but this was found to be too impure for fuel. Another small peat deposit was reported in Pleasant Valley Township, but the land upon which this peat occurred is now drained and under cultivation and the peat has been plowed into the soil.

There are no marshes in Mower County in which peat could form. The only areas of marshy land, with the exception of insignificant areas of an acre or two scattered here and there, lie in Lansing Township, (T. 103N., R. 18W.) in sections 20, 21, 28, and 29; and three small marshes in the northern part of Lyle Township (T. 101N., R. 18W.). These are all small narrow, shallow marshes, either along small creeks or in low pockets in the rolling prairie, and have mostly been drained and the land cultivated. The localities mentioned contain no peat but are covered with from one to several feet of peaty, black muck.

The absence of peat in Mower County is due to several factors, the chief of which are: (1) the absence of suitable depressions in the drift, the surface of which forms a generally level or slightly rolling prairie; and (2) the region lies on a relatively high divide which is therefore so well drained that no marshes have formed.

MURRAY COUNTY

Most of Murray County consists of a flatly rolling, poorly drained surface which slopes toward the northeast with a difference of about

500 feet in elevation between the southwest and northeast corners. The streams are not numerous and the land is dotted with lakes and marshes. These marshes, however, are not sources of peat in commercial quantities. According to Mr. R. F. Crim, Professor of Agriculture, Slayton State High School, who has made a study of the surface formations of the region, there are no peat deposits of importance in the county. This is probably due chiefly to the reason that most of the marshes are not wet enough in the dry season to prevent the decay of the plant remains.

NICOLLET COUNTY

There are no large swamps or marshes in Nicollet County but there are numerous small bogs, or meadows, most of which contain peat varying in thickness from 1 to 10 feet. These bogs are called "sloughs" and they occur in every township in the county. None of the Nicollet County deposits are comparable in extent, depth, quality, or quantity of peat, with the large peat bogs of northern Minnesota. Many of these small bogs in Nicollet County are used for hay meadows and pastures, as the areas usually produce a luxuriant growth of marsh grasses and sedges.

NOBLES COUNTY

Nobles County is traversed by a rather prominent morainic ridge which trends in a north-south direction approximately through the center of the county. East of this morainic belt there are a number of lakes, and the land is poorly drained. This is especially true of the southeast corner of the county, in Worthington, Loraine, Biglow, and Indian Lake townships.

Most of the marshes in Nobles County lie in the southeast corner, south and east of Worthington, in this poorly drained area; but none of them contain peat of commercial value. The only noteworthy peat deposit underlies Ocheda Lake, 2½ miles south of Worthington. This lake has been invaded by a dense growth of cattails, bulrushes, and giant sedges throughout its narrow western half, while these same plants are rapidly invading the wider eastern end, forming typical zonal growths 100 to 150 yards wide around the shores. In the parts of the lake thus invaded, there is peat several feet deep, but in order to render the material available, the lake would require draining, and the quantity of peat present does not warrant such measures.

Many of the areas which were formerly marshy are now drained and used for farm land. Winchell[84] gives the following localities which, in the early days of settlement, contained shallow peat deposits.

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[84] N. H. Winchell, Final Report, Minnesota Geological and Natural History Survey 1:532. 1882.

Dewald T. (102N., R. 41W.) Peat 14 inches thick.
Biglow T. (101N., R. 40W.) sec. 27. Peat 8 to 24 inches thick.
Indian Lake T. (101N., R. 39W.) sec. 4. Shallow turfy peat.

An analysis of peat from the last named locality given by Winchell shows H_2O, 11.93 per cent; Ash, 54.59 per cent; Organic matter, 33.48 per cent. From the analysis, the material would be classed as muck, or peaty soil. Most of the peat in the county is muck.

NORMAN COUNTY

There are three large marshes in the extreme eastern edge of Norman County which are covered with shallow deposits of peat, the average thickness being not more than 1 to 2 feet. The extent and distribution of these marshes may be seen on the large map (Plate I) accompanying this report. No samples of this peat were collected because it is too shallow to be valuable for fuel. These areas, however, after proper drainage, might have considerable agricultural value, for the peat could be plowed into the mineral soil.

The total area of peat land in the county is about 15 square miles.

OLMSTED COUNTY

The surface of the land in Olmsted County lies at an altitude of from 1,000 to 1,300 feet above the sea, and forms a part of the plateau of south central Minnesota. The region is drained by the Zumbro and Root rivers and their tributaries, which flow in valleys 200 to 300 feet deep. These streams have so dissected the land that the upland surface is not continuous, but consists of a series of ridges between stream valleys, especially in the southern portion of the county. This fact has an important bearing on the distribution of the peat deposits of the region. Because of the well developed drainage systems and the absence of suitable depressions in which marshes could form over most of the upland surface, the only deposits of a peaty nature are confined to areas along the stream valleys. Since these areas are subject to the annual overflow from the streams, they are kept in a marshy condition, and peat has accumulated in some places. The overflow from the creeks, however, washes in much silt and sand, which becomes mixed with the organic material from the plants, so that the peat there is very impure and approaches a muck in its constitution.

There are only five marshes in the county having more than five acres in area, three of which are in T. 106N., R. 15W., the fourth in T. 108N., R. 18W. in secs. 13 and 14; and the fifth and largest in sec. 33, Cascade T. 107N., R. 14W. one mile west of Rochester city limits. A part of this marsh is covered with a shallow deposit of rather impure peat, which is the only peat worthy of mention in the county. This deposit was tested with results given below. None of the peat deposits in

Olmsted County are of commercial value as a source of peat, but the land may all be used for pasturage, and some of the land, if drained, could be used to raise crops, especially garden vegetables.

ROCHESTER

Locality 98.—Sedge-grass marsh or meadow, 1 mile west of Rochester along Cascade Creek, sec. 33, T. 107N., R. 14W. The peat is underlain by black muck which rests upon clay. The deposit has formed along the bottom of the creek valley on land subject to overflow from the creek. The area comprises about 200 acres and the peat has an average thickness of 2 feet. It is black and silty, resembling muck rather than peat, and is composed chiefly of grass and sedge remains mixed with silt. Samples were collected from the top to the bottom of the peat from several test holes located on a line across the center of the bog. Analysis 146 (page 79) represents this marsh. The land can be used for pasture, but because it is subject to overflow from the creek, it is undesirable for farming. The peat has no value.

OTTER TAIL COUNTY

There were, before drainage, 162,000 acres of swamp and wet land in Otter Tail County. Only about half of this area, or 75,000 acres of this swamp land is covered with peat. Most of this area is made up of innumerable small bogs embracing a comparatively few acres each. A series of rugged moraines extends from north to south in a broad belt through central Otter Tail County and reaches west of the central part. This region is characterized by a topography almost as rough as any to be found in the northeastern part of the state. Throughout this morainic region are scattered hundreds of lakes, with still more numerous swamps and undrained areas. It is in this region that most of the peat occurs. The deposits are small and are for the most part unimportant, although some of them, which represent peat-filled lakes, are of considerable thickness. The bogs are mostly of two types: (1) small muskeg swamps covered with a heavy growth of tamarack or spruce, or (2) small treeless meadows of sedges and grasses. The peat consists chiefly of the remains of sedges and grasses, with pondweeds and other aquatic plants in some of the deeper bogs. In the eastern part of the county there are some rather large open marshes containing peat of considerable depth. Some of the deposits are of commercial value as sources of peat or peat fuel. Some typical bogs are described in detail below, and analyses of the peat are given.

PARKTON

Locality 231.—Cedar-tamarack swamp about 2 miles southwest of Parkton along the Northern Pacific railroad. This swamp is covered with cedar and tamarack trees and a few spruce. Grasses, sedges, and reed-grass, and some moss were noted in some places. The peat is underlain by sand. The area contains about 1,500 acres, and the average thickness of the peat as indicated by test holes is about 7 feet, with a maximum thickness of 9 feet. The peat is brown, rather plastic, and well decomposed. Sedge and reed remains were identified. The upper 4 feet of the deposit contains much wood.

Samples were collected every 2 feet from the top to the bottom of the peat from each of 3 holes as follows:

Hole 1—¼ mile east of west margin, along railroad; thickness 2 feet.
Hole 2—¼ mile east of No. 1; thickness 9 feet.
Hole 3—700 feet east of No. 2; thickness 6 feet.

Analysis 147 (page 79) represents average of these samples.

Locality 232.—This locality represents a part of the same bog as just described under Locality 231. This part of the bog is an open swamp or marsh, and the peat is underlain by marl. The deposit represents a filled lake. The vegetation at this locality shows a zone of cedars and tamaracks around the margin of the bog. Inside of this timbered belt is a zone 40 to 60 feet wide of sedges forming a quaking bog. Inside of this belt and forming the center of the bog, is an area of about 30 acres covered with reed-grass and cattails. The combined thickness of the peat and marl is from 10 to 12 feet. Considerable marl is mixed with the peat which is gray and structureless. Many shells were noted in both the marl and the peat.

Samples were collected one-half mile southwest of Parkton from test holes along a line 2,000 feet long southwest of and parallel to the railroad, in sec. 7, T. 133N., R. 37W. No analysis of the sample was made for the reason that the material contains more marl than peat. There is no good fuel peat in this vicinity, but the marl which occurs in the lower layers of the bog may be of value.

Locality 233.—This is part of the bog described under localities 231 and 232. The vegetation here consists of a zone of swamp-willows, within which is an open sedge-grass marsh or meadow. The peat in this part of the marsh, which is only 2 or 3 feet thick, is underlain by blue clay. The peat, which is of a light brown color, is fibrous and firm. It is composed of sedge and grass remains.

A composite sample was taken along a line beginning ¼ mile southwest of Parkton, and extending along the railroad to a point ¼ mile northeast of Parkton station. The location of the test holes is as follows:

Hole 1—½ mile west of Parkton; thickness 2 feet.
Hole 2—¼ mile west of Parkton; thickness 2 feet.
Hole 3—200 feet west of Parkton station (edge of island); thickness 1 foot.
Hole 4—700 feet east of Parkton; thickness 2 feet.

Analysis 148 (page 79) represents this sample. The bog here is too shallow for exploitation, but the land could be drained and put to some agricultural use.

RICHDALE

Locality 234.—Bog ¾ mile northwest of Richdale along Northern Pacific railroad. Sedges and grass predominate except at the north edge of the bog where swamp laurel, birch, and willows appear, associated with a few scattered tamarack. These trees merge into the hardwood timber of the dry land beyond the borders of the bog. The area contains about 100 acres and the average thickness of the peat is about 6 feet, with a maximum depth of 7 feet. The peat is brown and fibrous except the bottom layer about 1 foot thick which is black and structureless. It is composed chiefly of sedges, cattails, and reeds. Test holes were located as follows:

Hole 1—200 feet south of semaphore; ¾ mile northwest of station; thickness 3 feet.
Hole 2—200 feet north of semaphore; along railroad; thickness 7 feet.
Hole 3—¼ foot north of semaphore; thickness 6 feet.

Analysis 149 (page 79) represents this bog. The bog is surrounded by wheat fields which extend to the edge of the peat. The surface of the bog is smooth and clear, and the peat is of good quality for fuel.

Locality 235.—Open meadow or marsh, 1 mile southeast of Richdale along the Northern Pacific railroad. Sedges (*Carex*), grasses (red top), goldenrod, moss, and swamp laurel were the predominating plants growing on the surface. The peat is underlain by sandy till. The bog comprises an area of about 60 acres, and the average depth of the peat is 3½ feet. The peat is light brown in color, fibrous, and firm. It becomes rather plastic at 2½ feet in depth, and grades into black muck at the bottom of the deposit. It is somewhat gritty, due to sand. The upper layers consist chiefly of moss, sedges, and grass remains. An odor of hydrogen-sulphide gas was noticeable when taking the samples.

Test holes were located as follows:

Hole 1—200 feet west of mile post, 1 mile southeast of Richdale, 200 feet from edge of bog; thickness 2½ feet.
Hole 2—400 feet northwest of No. 1; thickness 3 feet.
Hole 3—400 feet northwest of No. 2; thickness 4 feet.
Hole 4—400 feet northwest of No. 3; thickness 4½ feet.

Analysis 150 (page 79) shows the composition of this peat.

Locality 236.—This is an open meadow or marsh in the center of sec. 34, T. 136N., R. 38W., one half of a mile southeast of Richdale along the Northern Pacific railroad. Portions of this peat marsh quake when walked upon. At the north end of the area the vegetation is typical of a sedge-grass meadow. There is a lake within the bog near the borders of which a zone of swamp birch, swamp laurel, and swamp-willow occurs, and between this zone of shrubs and the open water, there is a zone of reed-grass and cattails. The peat deposit represents a partially filled lake which merges into a built-up deposit extending out from the old lake shores. The combined area of the peat bog and lake is about 200 acres, 60 acres of which is included within the lake. The average thickness of the peat suitable for fuel is probably about 6 feet. The peat is brown in color and mossy or fibrous. The top of the deposit is made up of sedges and moss to a depth of 6 to 12 inches. Below this is a 2-foot layer of moss remains underlain by sedge-peat. At a depth of 6 feet black muck was encountered. Near the lake where the peat is of a different character, there is a 4-foot sedge mat, beneath which there is 5 feet of water. At the bottom of the bog beneath the water is a 2-foot bed of green pond peat. It thus appears that this lake is being filled with peat from both top and bottom. Test holes were located along a line through the center of the bog and parallel to its long axis as follows:

Hole 1—200 feet north of railroad, middle of bog; thickness 4 feet. Meadow, water covers surface.
Hole 2—200 feet south of railroad, middle of bog; thickness 5 feet. Meadow, water covers surface.
Hole 3—1,000 feet south of railroad; thickness 11 feet. Quaking bog.
Hole 4—2,000 feet south of railroad; thickness 12 feet. Edge of lake. Quaking bog.

Analysis 151 (page 79) shows the composition of a composite sample of this peat.

PENNINGTON COUNTY

Pennington County, which was organized in 1910 from a part of Red Lake County, has been covered by a detailed soil survey, under the Bureau of Soils of the U. S. Dept. of Agriculture. A soil map of the county has been made under the direction of Mr. W. G. Smith. The map shows in detail the distribution and area of the swamp or peat lands of the county. The largest of these swamps is shown on the large map (Plate I) accompanying this report. Pennington County has a total area of 607 square miles, of which 97 square miles, or 62,080 acres, are covered with peat. The peat deposits are practically all open, shallow, sedge-marshes, similar in every respect to the great open marshes of Marshall County and eastern Beltrami County, which adjoin Pennington County on the north and east respectively. The average thickness of the peat in these marshes does not exceed 3 feet. Pennington County lies wholly within the limits of glacial Lake Agassiz, which accounts, to a large degree, for the large area of undrained land within its borders. Much of the marshy land is being reclaimed by drainage for agricultural purposes, and eventually nearly all of it can be so used. The peat is too shallow for peat fuel.

PINE COUNTY

Pine County originally contained about 293,000 acres of swamp, or over-flowed land. A large part of this great area has been drained, and the land reclaimed. Many localities shown on old government and other maps as muskeg swamp, now show no evidence of their original character. Large areas in the county which were wet or swampy a few years ago are now good farms. There are still, however, large areas of swamp lands in the county. Many of these represent the deeper and lower portions of former large areas, the shallower parts of which have been drained, and the swamp vegetation burned. Most of the Pine County marshes were originally muskeg swamps, but there are few true muskegs left. Most of them have been burned, and the vegetation now existing furnishes only a clue, here and there, as to the original character of the plant life. The total area of peat land now existing in Pine County is approximately 75,000 acres. There are still some rather extensive peat swamps in the county. Most of the larger and more accessible bogs were examined and descriptions of these are given in the following pages. The best fuel peat was found near Kerrick (Locality 218) and Mission (Locality 221). Both of these bogs are large, and they contain deep deposits of good peat. They could be easily cleared, and they lie near railroads.

There is a bog at Groningen, crossed by the Northern Pacific railroad, from which small quantities of fuel peat were being taken at the time of visiting the locality. This bog is described under Locality 223.

The following descriptions include most of the bogs in the county which may possess a commercial value in the future, and they may be taken as typical of other deposits less favorably situated with respect to the railroad and which for that reason were not sampled.

BRUNO

Locality 217.—Burned muskeg ½ mile northeast of Bruno along Great Northern railroad. Sphagnum and polytrichiem moss, heath shrubs, a few swamp alders, and dead tamarack trees predominate. The peat is underlain by plastic white clay.

The area contains about 80 acres of peat which has an average depth of approximately 6 feet. The peat is brown, fibrous to decomposed, with a black, burned layer at 4 feet. The surface is covered with sphagnum moss, but most of the peat consists of the remains of sedges, reeds, and cattails. Test holes were located as follows:

Hole 1—300 feet east of margin of bog; thickness 5 feet.
Hole 2—200 feet east of No. 1; thickness 6 feet.
Hole 3—200 feet north of No. 2; thickness 5 feet.

Analysis 152 (page 79) represents this peat.

KERRICK

Locality 218.—Muskeg ½ mile south of Kerrick, in secs. 35 and 36, T. 45N., R. 18W. and sec. 2, T. 44N., R. 18W. The vegetation consists chiefly of tamarack and spruce trees, heath shrubs, giant sedges, sphagnum and polytrichiem moss, pitcher plants, and a few other species. The peat is underlain by sand. The deposit represents a peat-filled lake which has been built up above the old lake level by successive accumulations of plant remains.

The peat covers several square miles, and the average thickness of the deposit, as indicated by test holes, is about 14 feet. The character and composition of the peat varies with the depth, as follows:

Top; burned moss, 6 inches.
2 feet light brown, fibrous sedge-peat.
3 feet dark brown, plastic peat.
3 inches of black, structureless peat (probably burned).
2 feet grayish, stratified, fibrous sedge-peat.
3 feet red-brown, stratified, fibrous sedge-peat.
4 feet green, soft, structureless pond peat, composed of aquatic plants, at bottom.

Test holes were located along an east line parallel to the township line, starting at the corners of secs. 2 and 3, T. 44N., R. 18W., and secs. 34 and 35, T. 45N., R. 18W. as follows:

Hole 1—1,000 feet east of corner secs. 2, 3, 34, 45; 100 feet east of margin of bog; thickness 12 feet.
Hole 2—500 feet east of No. 1; thickness 18 feet.
Hole 3—500 feet east of No. 2; thickness 16 feet.
Hole 4—500 feet east of No. 3 (500 feet from margin of bog); thickness 10 feet.

Analysis 153 (page 79) shows the composition of a composite sample from these test holes. The portion of the bog which was sampled is deeper than at other places in the area. The north and south ends of the bog are shallow.

Locality 219.—This is part of the bog described under Locality 218. The area included under this locality comprises about 300 acres surrounding the station of Kerrick. The vegetation here consists of scrub tamarack about 6 feet high, heath shrubs, sphagnum and polytrichiem moss, and a few swamp alders. The peat is underlain by sand. The character and composition of the peat here, as elsewhere in this bog, vary with the depth below the surface. The top 12 inches consists of sphagnum peat, firm and stratified. From 1 to 14 feet the peat is fibrous, spongy, brown in color, and made up of the remains of sedges, reeds, and cattails. From 14 to 18 feet and deeper, the peat is green, soft, plastic, structureless material of the pond variety, composed of aquatic plants.

The average depth of the peat in this part of the bog is about 12 feet. The maximum depth, which is more than 18 feet, could not be determined with an 18-foot sounding rod. A composite sample was collected from test holes located as follows:

Hole 1—200 feet west of station; 100 feet east of edge of bog; thickness 18+ feet. Could not reach bottom.
Hole 2—¼ mile north of No. 1; thickness 12 feet.
Hole 3—¼ mile northwest of No. 2 at edge of bog; thickness 7 feet. Very large sphagnum moss to edge of lake.

Analysis 154 (page 79) represents this sample.

MISSION CREEK

Locality 220.—Bog beginning 500 feet south of the station at Mission Creek and extending about 1,500 feet south along the Northern Pacific railroad tracks. The area is partly an open marsh and partly a tamarack swamp. It was probably a muskeg originally and has been burned. The peat deposit fills a depression between low hills of glacial drift. The shore line is sharply marked. The vegetation consists chiefly of giant sedges, cattails, grasses, goldenrod, and a few scattered tamarack.

The bog contains an area of about 80 acres. The depth of the peat varies from 3 to 5 feet, with an average of 4 feet. It is brown, spongy to fibrous, with a woody layer near the surface, which is filled with logs, sticks, and roots. Below 3 feet in depth the peat consists chiefly of sedge and grass remains. Samples were taken every 2 feet from the top to the bottom of the peat from each of 3 holes, and also from the sides of a drainage ditch. The location of the test holes is as follows:

Hole 1—1,000 feet south of station along track. 500 feet south of margin of bog; thickness 3 feet.
Hole 2—250 feet south of No. 1; thickness 4 feet.
Hole 3—250 feet south of No. 2 (500 feet north of margin); thickness 5 feet.

Analysis 155 (page 79) represents this bog.

Locality 221.—Marsh 1 mile south of Mission Creek station along Northern Pacific railroad. This marsh has developed from a tamarack swamp as shown by the few remaining trees which still grow on the surface, and by the large number of dead trees and stumps buried in the upper 4 feet of peat. The vegetation consists chiefly of sedges, grasses, cattails, goldenrod, reed-grass, and a few scattered tamaracks. The deposit represents a peat-filled lake. The peat rests upon a sandy bottom.

The marsh covers an area of about 1 square mile. The peat is very deep, having an average thickness of about 10 feet, and a maximum thickness of more than 18 feet. The bottom of the deepest part of the bog could not be determined because sounding rods were too short. From the surface of the bog to a depth of 4 feet, the peat is red-brown, rather plastic, and contains many roots, stumps, and pieces of wood. From 4 to 6 feet the peat is decomposed and free from wood. From 6 to 10 feet the peat changes to light yellow-brown material of the fibrous sedge variety. From 10 to 18+ feet, greenish, soft, structureless pond peat occurs, which is composed of the remains of aquatic plants.

Test holes, from which a composite sample was obtained, were sunk along a north line, parallel to the railroad, as follows:

Hole 1—800 feet south of north margin of bog; thickness 10 feet of fuel peat. Total depth 18+ feet.
Hole 2—400 feet south of No. 1; thickness 10 feet of fuel peat; total depth 18+ feet.
Hole 3—400 feet south of No. 2 (800 feet from margin); thickness 10 feet of fuel peat. Total depth 18+ feet.

Analysis 156 (page 79) represents this sample. The peat will make good fuel, and the bog is well located for development.

FRIESLAND

Locality 222.—Open heath bog 1½ miles south of Friesland along the Northern Pacific railroad between the railroad tracks and the wagon road. The bog is covered by a growth of heath shrubs, polytrichiem moss, a few cattails, and scattered birch near the margins. A few dead tamarack trees occur also on the bog, which was probably once a tamarack swamp. There is evidence that the area has been burned and the original vegetation destroyed. The area comprises about 250 acres, and the average depth of the peat as indicated by test holes is approximately 5 feet. The peat is dark red-brown, fibrous, except near the bottom where it is somewhat plastic, and consists chiefly of the remains of sedges, grasses, cattails and heaths.

Test holes were sunk along a line through the middle of the bog at right angles to the railroad, and extending from the tracks to the wagon road. The location of the holes is as follows:

Hole 1—At edge of wagon road; thickness 2 feet.
Hole 2—800 feet west of No. 1; thickness 5 feet.
Hole 3—800 feet west of No. 2; thickness 6 feet.
Hole 4—800 feet west of No. 3; thickness 6 feet.

Analysis 157 (page 79) shows the composition of a composite sample taken from the bog.

GRONINGEN

Locality 223.—Peat meadow ½ mile southwest of Groningen along Northern Pacific railroad, in secs. 1 and 2, T. 42N., R. 21W. This bog has been burned and the original vegetation destroyed. Wild hay was being cut on the area at time of visit. The deposit probably represents a partially filled lake, a remnant of which still remains in the center of the bog. The combined area of the meadow and lake is about 100 acres. The average thickness of peat is approximately 6 feet, with a maximum thickness of 10 feet. The peat is light brown, firm, fibrous, stratified, and is composed chiefly of remains of sedges, cattails, reeds, and grasses.

Test holes were sunk along a line through the center of the bog at right angles to the railroad, and extending from the railroad to the wagon road. The location of the test holes is as follows:

Hole 1— At wagon road, ¼ mile from margin of bog; thickness 4 feet.
Hole 2—500 feet east of No. 1 along ditch; thickness 5 feet.
Hole 3—500 feet east of No. 2 along ditch; thickness 6 feet.
Hole 4—500 feet south of No. 3, at edge of lake; thickness 10 feet (sedge mat).

Analysis 158 (page 79) is of a composite sample from these holes. This is a splendid fuel peat deposit. In digging the ditch across the bog each spade-full of peat retained its shape, and these blocks were piled to one side to dry and are now being used for fuel by the owner of the bog. The Northern Pacific railroad crosses the property. The bog is well drained and the surface is firm enough to support a team of horses, even to the edge of the pond. Nearby are 2 similar small bogs of about 50 acres each, one to the east and the other to the southeast of Groningen, which contain peat of the same type.

STURGEON LAKE

Locality 224.—Open bog containing small lake, ½ mile south of Sturgeon Lake station along the Northern Pacific railroad. Sedges, grasses, swamp birch, heath shrubs, sphagnum moss, pitcher plants, and a few small dead cedar trees make up the vegetation on this area. Big sedges near the edge of lake form a quaking sedge mat. The lake shows a well-defined zone of water-lilies. The deposit represents a peat-filled lake in a depression between morainic hills.

The area contains about 200 acres including the small lake. The average thickness of the peat is 9 feet with a maximum thickness of 14 feet. The character and composition of the peat varies with the depth below the surface. From the surface to 8 feet, the peat is brown, fibrous to spongy, stratified, and consists chiefly of sedges, cattails, reeds, twigs, etc. with roots and pieces of wood near the surface. In the center of the bog this peat is rather fluid. From 8 to 10 feet the peat is red-brown and mossy and contains much woody fibre. From 10 to 14 feet the peat consists of green, soft, and structureless material of the pond or filled-lake variety.

A composite sample was taken from test holes located along an east line across the bog perpendicular to the railroad, ½ mile south of Sturgeon Lake station. The location of the test holes is as follows:

Hole 1—40 feet east of railroad track; thickness 5 feet. Brown, fibrous, sedge-peat.
Hole 2—1,000 feet east of No. 1, between 2 small ponds; thickness 14 feet. Bottom 3 feet is green pond peat.
Hole 3—1,000 feet east of No. 2; thickness 11 feet. 1 foot thick at bottom. Green pond peat.

Analysis 159 (page 79) represents this sample. The occurrence of a layer of moss peat near the bottom, beneath 8 feet of sedge-peat, is unusual. The surface of this bog is clear and level and the deposit could be used for fuel.

PIPESTONE COUNTY

Pipestone County is crossed near the northeast corner by a morainal ridge which marks the divide between the Mississippi and Missouri river basins. South and west of this moraine the land surface forms a well drained upland and is free from lakes and marshes. Most of the county lies southwest of this divide and hence there are no peat deposits of importance in the county. The only marshy tract lies in T. 108N., R. 46W. along Flandreau Creek. This stream flows in a valley having a general northeast-southwest trend and on both sides of the creek there are long narrow tracts of wet land. This valley bottom, however, is mostly silt, and no peat of importance exists there.

POLK COUNTY

Polk County contains about 65,000 acres of swamp land, most of which is covered with peat. The peat is shallow, and few, if any, deposits are of sufficient thickness for fuel. The areas and distribution of the swamps in this county are shown on the large map (Plate I) accompanying this report. It will be seen from this map that most of the swamps are in the extreme eastern part of the county, where the big swamps of western Beltrami County extend into Polk County. The only locality sampled was a large peat marsh in the southwest part of the county. The description of this peat is given below. The eastern bogs are similar in every way to those of western Beltrami County.

BELTRAMI

Locality 140.—This is a part of a large open marsh which covers an area of about 10 square miles. The portion of the marsh described here is that along the road extending north and south along a line between secs. 14 and 15, T. 147N., R. 47W., 4 miles west of Beltrami and 14 miles south of Crookston. A large part of this marsh is now planted with flax. The original vegetation consisted of sedges, grasses, and reed-grass. The peat has been built up on a flat, undrained surface by successive accumulations of peat-forming plants. The peat is underlain by lake-washed till, which represents a part of the old bed of glacial Lake Agassiz.

The average thickness of the peat here is only 1½ to 2 feet. The peat is brown, firm, fibrous, and silty, and shows marked stratification. It is covered with a white efflorescence of soluble salts on freshly exposed surfaces. The peat is made up chiefly of the remains of grasses, sedges, reeds, and cattails. No moss or trees were noted.

Test holes were sunk along the section line between secs. 14 and 15, T. 147N., R. 47W. The thickness of the peat is also exposed in the drainage ditch along the wagon road.

Analysis 160 (page 79) shows the composition of a composite sample taken from test holes and along the sides of the drainage ditch. The marsh is all drained by large ditches. The peat is very shallow and is of no value for fuel. The land is valuable for farming, and considerable flax has already been planted on drained portions.

POPE COUNTY

No peat deposits in Pope County are large or deep. At none of the localities visited was peat seen of sufficient depth or purity to be of value for fuel or other purposes. Most of the swamp land in the county occurs in small areas around lakes or along streams or "sloughs," and the decaying vegetable matter in these deposits is usually mixed with silt or sand.

RAMSEY COUNTY

Ramsey County, in which the city of St. Paul is located, contains very little swamp land. The total area of peat land in the county is about 1,500 acres. This is all situated in the northern part of the county, especially in the lake region in the northeast quarter of the county. The peat occurs in small bogs, none of which contain more than a few hundred acres. Most of the bogs are associated with lakes, and some of the peat deposits are deep.

The following descriptions are typical of the 2 types of bogs found in the county: meadows and burned muskegs.

ST. PAUL

Locality 83.—Open sedge-marsh or meadow of the quaking bog type, in secs. 20, 28, and 29, T. 30N., R. 22W.; about 5 miles north of St. Paul. The vegetation consists mostly of sedges and grasses with a thin layer of moss at the grass roots. Around the margin of the bog there is a zone of large sedges (wire grass) and blue-grass. The marsh is evidently a peat-filled lake. The old shore line is still plainly visible and remains of sand beaches may be seen. The peat is underlain by sand.

The area comprises about 500 acres, and the average thickness of the peat, as indicated by test holes, is about 6 feet. The peat is soft, plastic, decomposed, and of a yellow-brown color. It is made up chiefly of sedges and grasses, with the remains of aquatic plants near the bottom.

A composite sample was collected from test holes located along the south line of the northwest quarter of section 28.

Analysis 161 (page 79) represents this sample. This is a good peat fuel deposit. A good crop of wild hay was being cut on this land at the time of examination, and the owner of the property had under consideration the construction of a complete system of drainage ditches.

Locality 84.—Bog in the SW¼ of sec. 9, T. 30N., R. 22W., east of Black Lake. The bog has been well drained, and the natural vegetation of sphagnum and heath has given place to a dense growth of alders and willows, with grasses and sedges. Where the brush has been cleared, sedges and grasses predominate. The peat deposit, which represents a filled lake or pond, is underlain by clay. The bog comprises an area of about 200 acres. The deposit contains from 6 to 8 feet of fuel peat underlain by 8 feet of marly pond peat. The upper 6 or 8 feet consists of mossy, spongy, brown peat, made up entirely of sphagnum and sedge remains. The bottom pond peat consists of aquatic plants, with marl and fragments of shells. A composite sample was taken of the upper 6 or 8 feet of fuel peat. The underlying green, marly, pond peat was sampled and analyzed separately. (See Locality 85.)

Analysis 162 (page 79) shows the composition of the upper 6 feet of fuel peat. The upper 4 feet of this deposit is excellent peat for packing or peat litter. The open fissure at the roadside was caused by dumping a large amount of "fill" for the roadbed on the bog before it was drained. The weight of the gravel broke the 6 foot moss mat, which rested upon the fluid pond peat, and the soft, semi-fluid underlying peat thrust up the surface of the bog at one side of the road 8 feet above the general surface.

This deposit furnishes a good illustration of a "climbing bog." The peat has gradually spread up the lower slopes of a hill at the north edge 10 or 12 feet above the general level of the bog.

Locality 85.—This sample represents green, marly, pond peat which lies beneath the fuel peat described under Locality 84.

Analysis 163 (page 000) shows the composition of this material.

Locality 251.—Bog ½ mile east of Bald Eagle, near the boundary of Ramsey and Washington counties, in sec. 1, T. 30N., R. 22W. The vegetation of this bog consists chiefly of sedges, sphagnum moss, grasses, tamaracks, and spruce. The deposit represents a peat-filled lake and is underlain by sand. The area occupied by the peat consists of about 360 acres. The average depth of the peat is approximately 12 feet with a maximum thickness of 16 feet. The peat is light brown, and fibrous to a depth of 10 feet, below which occurs structureless green pond peat.

Samples were taken every 2 feet in depth from the surface of the bog, to a depth of 10 feet which represents the lower limit of fuel peat. None of the bottom pond peat was included in this sample. The location of the test holes is as follows:

Hole 1—200 feet from margin; at edge of tamarack grove; thickness 16 feet.
Hole 2—500 feet west of No. 1; thickness 12 feet.
Hole 3—500 feet west of No. 2; thickness 6 feet.
Hole 4—300 feet west of No. 3; thickness 12 feet.
Hole 5—200 feet west of No. 4; thickness 12 feet.

Analysis 164 (page 79) shows the composition of the peat. This is excellent fuel peat and the deposit is within about 500 feet of the Northern Pacific railroad. The locality is only a few miles north of St. Paul, and the conditions are favorable for its development. Considerable clearing would be required on some parts of the bog, and the area would have to be drained, as portions of the deposit constitute "quaking bogs."

RED LAKE COUNTY

Red Lake is a small county situated between Pennington County, on the north, and Polk County on the southwest and east. It lies entirely within the limits of what was once glacial Lake Agassiz and the surface is generally flat. The total area of swamp or moist land in the county is about 17,000 acres and most of this is covered with peat. The peat, however, is all shallow and no deposits of fuel value were found. Most of the peat marshes lie in the extreme eastern part of the county. The marshes are treeless and covered with a heavy growth of sedges (mostly *Carex*) with some grass and a little moss. Cattails and reed-grass occur in spots, and occasionally groups of marsh willows, or swamp birch and alders were seen. The peat is so shallow that much of the land is probably reclaimable for agriculture.

REDWOOD COUNTY

There is very little peat in Redwood County and no deposits were found of value for fuel or peat litter. There are numerous small marshy tracts of land in the county, but most of these contain black muck.

RENVILLE COUNTY

No important peat deposits exist in Renville County, although there are numerous small peaty sloughs and marshes. There were originally 120,000 acres of wet or overflowed land in Renville County.[85] Very little of this land, however, is peat covered, and most of the peat that does exist is shallow, silty, and occurs in small patches. The majority of the bogs are found along streams. The deposits were not considered of sufficient value to warrant sampling.

RICE COUNTY

There are about 65 peat bogs in Rice County, as shown on the reference Soil Map of Rice County, by the Bureau of Soils, U. S. Dept. of Agriculture. All of these peat deposits lie west of a north-south line drawn through Faribault, the county seat, which is approximately in the center of the county. Nearly all of the peat deposits lie in the northwest quarter of the county, and are associated with lakes which occur in the morainic belt of that region. The peat bogs are all comparatively small, and seldom contain more than 160 acres, although a few attain an area of 500 acres or more. The bogs are all open sedge-grass marshes and meadows. No muskegs exist this far south. No sphagnum was found in any of the Rice County bogs. They resemble the peat deposits of Blue Earth County which were described in detail in the preceding pages. The peat in the Rice County meadows is composed almost entirely of sedge and grass remains, and the thickness varies from a few inches to 12 or 15 feet. Some of the few deeper bogs, are filled lakes.

Only a few of these peat marshes, in the extreme northeastern part of the county, occur along a railroad, so that it seems improbable that any attempt will be made in the near future to utilize the peat for fuel. The land is now being used for pastures and hay meadow.

The following description of a typical peat bog in Rice County illustrates the character of the peat in these deposits.

NORTHFIELD

Locality 254.—Quaking bog of the open marsh type about 9 miles west of Northfield in sec. 3, T. 111N., R. 21W. Vegetation on this bog consists chiefly of sedges, reed-grass, cattails, moss, and swamp-willows. The deposit represents a filled lake. The area consists of about 300 acres, and the average depth of the peat, as indicated by test holes, is approximately 6 feet. The maximum thickness is 9 feet. The peat is brown and fibrous, to a depth of 5 feet beneath which occurs soft, structureless, green, pond peat. Test holes were sunk along a line from the center of section 3, southward to the south edge of the section as follows:

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[85] George A. Ralph, Engineer's Report on State Drainage Commission on Drainage Work in Minnesota, p. 140. 1913.

Hole 1—100 feet south of north margin of bog; thickness 7 feet. Lower 3 feet is green pond peat.
Hole 2—200 feet south of No. 1; thickness 6 feet. Lower 3 feet green pond peat.
Hole 3—200 feet south of No. 2; thickness 9 feet. Lower 6 feet green pond peat.
Hole 4—200 feet south of No. 3; thickness 6 feet. Lower 2 feet green pond peat.
Hole 5—300 feet south of No. 4; thickness 5 feet. An island is located between holes 4 and 5.
Hole 6—200 feet south of No. 5; thickness 4 feet.
Hole 7—200 feet south of No. 6; thickness 3 feet.
Hole 8—200 feet south of No. 7; thickness 4 feet.

Analysis 165 (page 79) shows the composition of a composite sample from these holes.

ROCK COUNTY

Rock County is better drained than most of the southern counties in Minnesota. The principal drainage system is Rock River and its tributaries, which flow through the eastern portion of the county. As a result of the better drainage, there are practically no lakes or swamps in Rock County, and consequently no peat deposits. The only wet areas lie in the extreme northwest corner of the county in T. 104N., R. 46W. In this township there is a small marsh between sections 5 and 6, and another long narrow one along a creek extending through parts of secs. 6, 7, 18, and 19. None of these areas, however, contain any peat worthy of mention, and the land is being drained to render it available for farming.

ROSEAU COUNTY

Roseau County, with an area of 1,670 square miles, contains 550 square miles,[86] or 352,000 acres of swamp land, most of which contain peat. The areas and distribution of these swamps are shown on the map (Plate I) accompanying this report. Most of the peat swamps occur in the northern, eastern, and southeastern parts of the county. The peat in the south and eastern parts of Roseau County is shallow, and the greater portion of the northern swamps also contains peat less than 6 feet thick. There are in the north, however, places where the peat is 18 to 20 feet deep over considerable area. Most of the peat areas consist of open, treeless sedge-marshes, having a smooth, flat, but not level, surface. The surfaces of the big marshes in the southwest part of the county have slopes varying from 2 to 6 feet per mile. In the northwestern and central parts of the county, the swamps in the drainage area of the Roseau River have surface slopes of 3 to 6 feet per mile. There are, in addition to the sedge-marshes, many square miles of muskeg swamps timbered with scrub tamarack and spruce. One of the largest of these muskeg swamps occurs around Roseau Lake, a few

[86] Frank Leverett, and U. G. Purssell, *op. cit.* p. 45.

miles south of the Canadian boundary, in the north central part of the county.

Thousands of acres of swamp land in the county have been burned, and some areas have been burned several times at long intervals, as shown by the records in the peat deposits. This fact may explain why most of these peat areas are so shallow.

The state has already constructed many miles of excellent drainage ditches through the swamps of Roseau County, and a still greater mileage of ditching is now projected. This drainage, particularly in the shallow swamps where the peat is less than 4 feet deep, has resulted in large areas being reclaimed for agriculture. But an area of more than 100 square miles of swamp, especially in the northern part of the county, is so deep and so wet that the land can be reclaimed only with great difficulty. Most of the peat is too shallow to be worked for machine peat. Much of this shallow peat is suitable for packing or peat litter.

Roseau County lies in the area once covered by glacial Lake Agassiz, which accounts, in a large measure, for the low swampy nature of so much of its surface. The peat is underlain by clayey to sandy lake-washed glacial material. Clay predominates under the northern bogs, while in the southern marshes, the subsoil is sandy.

Many places were visited, examined and sampled. The following descriptions are given as typical of the largest swamps in the county.

Locality 128.—Part of same bog as just described under Locality 127. The peat at this locality has an average depth of only 2½ feet. A composite sample was collected from points every ¼ mile for a distance of 2 miles, beginning at the drainage ditch at the roadside and extending along a north-south line between secs. 15 and 21 and 16 and 21.

No test holes were necessary since the thickness of the peat is exposed in the sides of the ditch.

Analysis 167 (page 79) represents this sample. The peat here is too shallow to be of any value as a source of peat fuel. It would make excellent peat litter or packing material. If the bog were thoroughly drained, a large part of the area could probably be used for agricultural purposes.

ROSEAU

Locality 180.—Open sedge-marsh beginning 2 miles east and ¼ mile north of Roseau, and extending north and east of Roseau. This is a part of the "Great Swamp" of Roseau County which covers more than 100 square miles. The swamp occupies a part of the old bed of glacial Lake Agassiz. The peat is underlain by clay, sand, and till. The marsh is a built-up deposit of the high-moor type. The vegetation consists chiefly of sedges and grasses.

The thickness of the peat in the Great Swamp varies. At this locality the average thickness is 4 feet. The peat is light brown, spongy, fibrous, firm, and rather dry compared to the muskeg swamps of northern Minnesota. It is composed chiefly of sedges with a layer of cattails, bulrushes, etc. in the upper 2 feet of the deposit. No wood was found in the peat at this locality.

A composite sample was taken from secs. 16 and 17, T. 162N., R. 39 W. The samples were obtained from test holes located as follows:

Hole 1—¼ mile north of corner of secs. 16, 17, 20, and 21; thickness 4 feet.
Hole 2—½ mile north of corner of secs. 16, 17, 20, and 21; thickness 4 feet.
Hole 3—¾ mile north of corner of secs. 16, 17, 20, and 21; thickness 4 feet.
Hole 4—Corner secs. 8, 9, 16, and 17; thickness 3 feet.

Analysis 168 (page 79) represents this sample. This is an enormous open marsh which appears flat and smooth, as far as the eye can reach.

CEDARBEND

Locality 127.—This is a portion of an immense bog extending over at least 15 square miles in this region. The locality here described lies in the SE¼ of sec. 2; NW¼ sec. 11; and SE½ of sec. 10, T. 162N., R. 37W. (Cedarbend Township). The area here is an open marsh surrounded by a spruce-tamarack-cedar swamp. The whole area was once a muskeg and has been burned by a big fire, which killed the vegetation in the central part, and destroyed the original character of the bog. The surface is firm and well drained. Two types of vegetation were noted. The center of the bog contains 8 or 10 square miles of treeless, open sedge-marsh. Around the edge of this open marsh there is a zone of tamarack, spruce and cedar trees, about 1 mile wide in some places. The peat represents a built-up deposit formed on the old bed of glacial Lake Agassiz. The peat is underlain by gray or yellowish clayey till. The average thickness of the peat in this portion of the bog is about 4 feet. The maximum thickness is about 6 feet. No test holes were put down as it was not necessary, due to the exposure of the total thickness of the peat along the drainage ditches which cross the bog. A composite sample was collected along the ditch at the roadside, cutting diagonally northeast and southwest across the sections named above. The sample represents a distance of two miles along the ditch.

Analysis 166 (page 79) shows the composition of this peat. This is one of the best looking peat fuel bogs seen in northern Minnesota. It is near the railroad and no clearing or other preparation of the surface would be necessary. The peat, however, is somewhat shallow in this portion of the bog. Before any development is undertaken test holes should be put down systematically over a considerable area, to locate if possible a thicker portion of the deposit.

The marsh is well drained by numerous large drainage ditches 8 to 10 feet deep.

Locality 181.—This locality is in the swamp described under Locality 180. The character and composition of the peat, as well as the type of vegetation on the bog, are the same as described. The average thickness of the peat is 4 feet, and the maximum thickness as indicated by test holes is 5 feet. Sampling was continued northward along the same line of test holes, beginning 2 miles east and 1 mile north of Roseau, and extending north for 1 mile along the section line.

The location of the holes is as follows:

Hole 1—¼ mile north of secs. 8, 9, 16, and 17; thickness 4 feet.
Hole 2—½ mile north of secs. 8, 9, 16, and 17; thickness 4 feet.
Hole 3—¾ mile north of corner of secs. 8, 9, 16, and 17; thickness 4 feet.
Hole 4—Corner of secs. 4, 5, 8, and 9; thickness 5 feet.

Analysis 169 (page 79) represents the peat in this portion of the swamp. The firmness of the peat in this marsh is unusual. The sides of the ditch, which was excavated 12 years ago, still remain perpendicular and smooth, as when first dug.

Locality 182.—Another portion of the swamp described under preceding locality. The average thickness of the peat is 4 feet. A composite sample was taken from test holes located as follows:

Hole 1—¼ mile east of corner of secs. 8, 9, 16, and 17; thickness 3 feet.
Hole 2—½ mile east of corner of secs. 8, 9, 16, and 17; thickness 4 feet.
Hole 3—¾ mile east of corner of secs. 8, 9, 16, and 17; thickness 4 feet.
Hole 4—Corner of secs. 9, 10, 15, and 16; thickness 4 feet.

Analysis 170 (page 79) shows the composition of this sample.

Locality 186.—Another portion of the Great Swamp. This locality represents an area 7 miles north of Roseau. The vegetation includes tamaracks and cedars in addition to the usual sedges, heaths, sphagnum, reed-grass, cattails, etc., found throughout the great swamp. The peat is underlain by sand.

The average thickness of the peat is 4 feet, but the thickness varies from 3 to 5 feet. The peat is red brown, woody, and fibrous, and is composed chiefly of sedges, reeds, cattails, twigs, and much wood in the upper layers.

A composite sample was taken from test holes along a line beginning at the southeast corner of sec. 12, T. 163N., R. 40W., and extending northward 1 mile along the line between ranges 39 and 40W. The location of the test holes is as follows:

Hole 1—¼ mile west of creek; 200 feet from margin of bog; thickness 3 feet. Peat is fluid.
Hole 2—¼ mile west of No. 1; thickness 3 feet. Open marsh here.
Hole 3—¼ mile west of No. 2; thickness 4 feet. Dense tamarack grove.
Hole 4—¼ mile west of No. 3; thickness 5 feet. Cedars and tamarack.

Analysis 174 (page 79) represents this locality. Considerable timber has been cut on this swamp.

Locality 187.—Another part of the Great Swamp. This is a muskeg phase of the swamp, located 8 miles north and 1 mile east of Roseau. Tamaracks, cedars, swamp-willows, sedges, reed-grass, sphagnum and polytrichiem moss predominate among the plants growing on the surface.

The peat here is from 2 to 5 feet thick, with an average thickness of about 3 feet. It is red-brown in color, fluid, and structureless, thus differing from the firm, fibrous peat found in the other portions of the swamp described in the preceding paragraphs.

A composite sample was taken from test holes located as follows:

Hole 1—Southeast corner sec. 6, T. 163N., R. 39W.; thickness 2 feet. In a hay meadow.
Hole 2—¼ mile north of No. 1; thickness 2½ feet. Brown decomposed peat.
Hole 3—¼ mile north of No. 2; thickness 3 feet. Typical muskeg.
Hole 4—¼ mile north of No. 3; thickness 5 feet. Typical muskeg.

Analysis 175 (page 79) represents this peat. The dense growth of tamaracks renders the peat in this part of the swamp of no commercial value as a source of fuel.

Locality 188.—This is a continuation of Locality 187. Sampling was extended northward from Hole No. 4 of that locality. The average thickness of the peat here is 9 feet. It is light brown, fibrous peat of uniform texture, and is composed of fine threadlike roots and remains of sedges, cattails, reeds, etc. Only 2 test holes were sunk at this locality, one at the northeast corner of sec. 6, T. 163N., R. 39W., and the other ¼ mile north of No. 1.

Analysis 176 (page 79) represents this locality. There is an area of several square miles nearby where the peat is deep and of excellent quality, and where the surface is comparatively clear. This area is surrounded by a dense shallow swamp of the type of localities 186 and 187.

SALOL

Locality 183.—Quaking bog 6 miles north and 4 miles west of Salol. This is also a part of the same immense marsh described in the preceding paragraphs. The vegetation here consists chiefly of sedges, sphagnum moss, reed-grass, swamp ferns, a few cattails, swamp laurel, swamp-willows, swamp birch, buck bean, and dead tamaracks. The peat is underlain by brown clay and below that by white or buff clay. About 2 inches of water covered the surface of the bog at the time of examination.

At this locality the peat varies in thickness from 14 to 18 feet. It is light brown, fibrous, and of uniform texture, and is composed chiefly of sedges, reeds, cattails, and parts of shrubs. Woody layers occur at a depth of 4 feet and 12 feet below the surface.

A composite sample was taken from test holes located on a line 2 miles in length along the north-south section line between secs. 1 and 2, T. 163N., R. 38W.; and secs. 35 and 36, T. 164N., R. 38W. The location of the holes is as follows:

Hole 1—At southwest corner sec. 1; thickness 17 feet. Sedges and shrubs predominate.
Hole 2—¼ mile north of No. 1; thickness 18 feet. The peat is rather fluid.
Hole 3—¼ mile north of No. 2; thickness 16 feet.
Hole 4—¼ mile north of No. 3; thickness 14 feet.
Hole 5—¼ mile north of No. 4; thickness 15 feet.
Hole 6—¼ mile north of No. 5; thickness 14 feet. Large area of cattails.
Hole 7—¼ mile north of No. 6; thickness 15 feet. With outer zone of reed-grass.

Because of the fluidity of the peat, it was difficult to get samples at depth. The peat would run out of the cylinder of the sampler before it could be drawn to the surface. Samples were taken whenever possible every 2 feet in depth from the top to the bottom of each hole.

Analysis 171 (page 79) shows the composition of this peat. The marsh was flooded at time of examination. The water was so high that the lower floor of a settler's cabin on the marsh was submerged.

Locality 184.—This also represents a part of the Great Swamp described under the preceding locality. The vegetation at this point on the marsh consists of sedges, cattails, and heaths. The peat here is from 15 to 17 feet deep. It is light brown, and fibrous. The deposit contains numerous tough fibrous mats or layers, 1 to 2 feet apart, and separated by layers of fluid, watery peat. The material is composed chiefly of the remains of sedges, reeds, cattails, and heaths to a depth of 12 feet. Below 12 feet the peat consists almost entirely of sedge remains. Test holes were located as follows:

Hole 1—At northwest corner of sec. 1, T. 163N., R. 38W.; thickness 16 feet.
Hole 2—¼ mile east of No. 1; thickness 15 feet.
Hole 3—¼ mile east of No. 2; thickness 14 feet.
Hole 4—¼ mile east of No. 3; thickness 17 feet.
Hole 5—¼ mile east of No. 4; thickness 16 feet.

Analysis 172 (page 79) represents this portion of the marsh which here is not drained. The surface is entirely under water, and the peat is saturated.

Locality 185.—This also is a portion of the Great Swamp, and represents an area 1 mile west of Salol. The swamp here has been partly cleared, and several farms have been located on the peat land. The original vegetation consisted of sedges, swamp-willows, swamp birch, and other bushes, with grasses and cattails. The area here has been inundated by the overflow from Hay Creek, which formerly flowed here, but which has been controlled by drainage ditches. The peat is underlain by clay.

The average thickness of the peat here is only 2 feet. It consists of light brown fibrous material containing much sand or silt.

Sampling was started at mile post 91 along the Great Northern railroad, and test holes were put down as follows:

Hole 1—At mile post 91; thickness 1 foot.
Hole 2—At mile post 90¾; thickness 4 feet. A few swamp-willows.
Hole 3—At mile post 90½; thickness 3 feet.
Hole 4—At mile post 90¼; thickness 1½ feet.
Hole 5—At mile post 90; thickness 1 foot. Dead birch trees.
Hole 6—At mile post 89¾; thickness 1 foot. This locality is being farmed and hay and corn are growing on the land.

Analysis 173 (page 79) represents this portion of the marsh. Hay Creek enters the Great Swamp at this locality, and an arm of the marsh extends up the valley of Hay Creek for a long distance. The gritty character of the peat is due to the overflows of Hay Creek which have washed in silt.

CLEAR RIVER

Locality 191.—Burned muskeg 14 miles south of Warroad in secs. 9 and 16, T. 161N., R. 36E. Dead tamarack and spruce trees, grasses, and sedges, and many kinds of weeds cover the burned area. The peat represents a built-up deposit of the high-moor type. This locality represents a portion of a very large marsh. The peat here has a thickness of only 1 foot. It is distinctly fibrous and but slightly decomposed. Grasses, sedges, and heath roots predominate in the peat. Samples were taken from test holes located along a north-south line through the center of secs. 9 and 16 as follows:

Hole 1—¼ mile north of corner secs. 16, 17, 20, and 21; thickness 1½ feet.
Hole 2—¼ mile north and ¼ mile east of No. 1; thickness 1 foot.
Hole 3—¼ mile north of No. 2; thickness 1½ feet.
Hole 4—¼ mile north of No. 3; thickness 1 foot.
Hole 5—¼ mile north of No. 4; thickness 2 feet.
Hole 6—¼ mile north of No. 5; thickness 8 inches.

Analysis 177 (page 79) represents this peat. The deposit is too shallow to be of value for fuel, but the land could be reclaimed for agriculture.

AMERICA

Locality 192.—Marsh in secs. 4 and 9, T. 161N., R. 37W. (America Township). The area has been burned, and the vegetation now consists chiefly of sedges, grasses, polytrichiem, and a little sphagnum. At the east end of the area there are dead tamarack and spruce trees, 4 to 6 inches in diameter. Elsewhere on the bog there are no trees. The peat rests upon sand. The marsh covers an area of about 2 square miles.

The average thickness at this point is 2½ feet, and the maximum thickness is 4 feet. Test holes were located as follows:

Hole 1—At corner secs. 3, 4, 9, and 10, T. 161N., R. 37W.; thickness 2 feet.
Hole 2—¼ mile west of No. 1; thickness 4 feet.
Hole 3—¼ mile west of No. 2; thickness 2½ feet.
Hole 4—¼ mile west of No. 3; thickness 2 feet.

Analysis 178 (page 79) represents this locality.

WARROAD

Locality 193.—This is a part of an immense swamp extending for several miles south from the shore of Lake of the Woods. The character of the bog varies from open marsh to typical muskeg. The peat is underlain by sand or sandy clay.

The peat varies in thickness from 3 to 7 feet. It is brown in color, and fibrous to spongy. Near the lake shore the peat consists chiefly of reed-grass, sedges, cattails, and moss, and it is contaminated with considerable sand and silt washed in by the lake. Back from the shore ½ mile, sedges and heath shrubs are prominent. The samples near shore were collected from a boat, as the surface of the bog was covered with several feet of water. The peat was so fluid it would not always remain in the cylinder of the sampler, but wherever possible samples were taken every 2 feet from top to bottom of the peat. All were mixed in a sample sack.

Analysis 179 (page 79) represents this peat. The sample was collected along the lake shore and represents peat close to the shore. Further inland from the lake the swamp is a typical muskeg and the peat as exposed in drainage ditches, has an average thickness of 5 or 6 feet. At the shore line the waves have piled up the peat in a long ridge, about 2 feet high.

ST. LOUIS COUNTY

St. Louis County, which is the largest in the state, has a swamp land area of approximately 1,192,160 acres, or more than ¼ the area of the entire county. It is one of the three largest peat-land counties in Minnesota. The most extensive swamps lie in the southwest portion, but hundreds of swamps of all sizes are located throughout the county. The distribution of these swamps is shown on the map of St. Louis County (Figure 7), and also on the large map (Plate I) accompanying this report. The great majority of the swamps of this county are covered with a rather heavy forest of tamarack, black spruce, or swamp cedar. Within these swamps are numerous open heath bogs, in which there are only scattered patches of scrub tamarack or spruce. The area of open bogs in the county is about one fifth of the total swamp area.

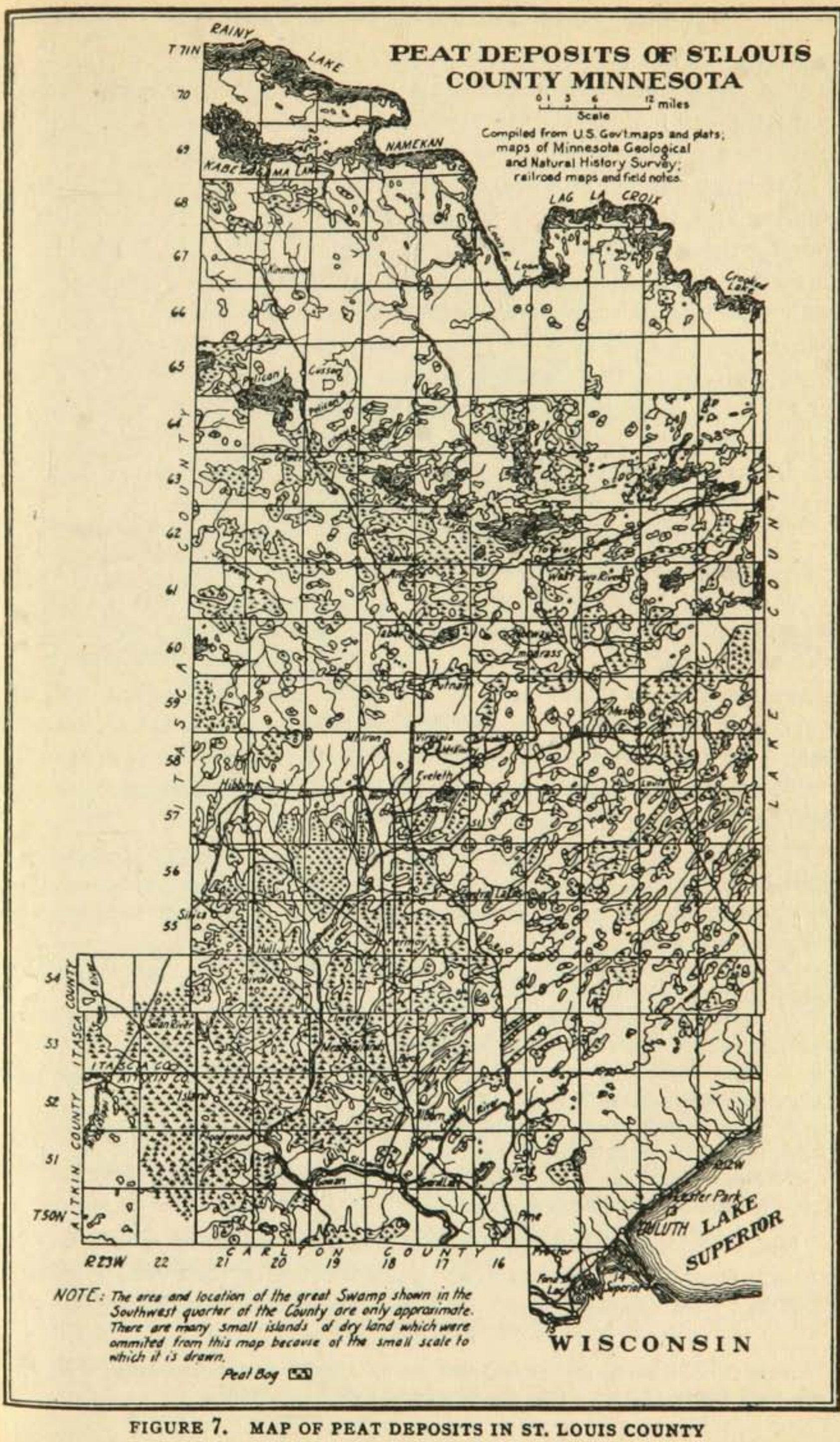

FIGURE 7. MAP OF PEAT DEPOSITS IN ST. LOUIS COUNTY

Most of these open bogs occur around lakes or along streams. In the northern portion of the county the bogs are more numerous and smaller, but there are many areas containing 5 or 6 square miles.

The large number of lakes, especially in the northern part of St. Louis County, and the numerous streams greatly simplify the problems of draining these swamps. The surfaces of many of the larger swamps in the county have a slope sufficient to give good drainage at comparatively small cost. In the northern portion of the county, many of the bogs have slopes as high as 4 to 10 feet per mile, while the surface of the larger swamps on the southern portion have slopes of from 2 to 6 feet per mile. A large mileage of drainage ditches is already completed in the southwestern part of the county, and additional ditches are being constructed each year. These ditches are of large cross-section and will serve as mains into which, later, laterals may be carried.

The depth of the peat throughout the swamps of the county is variable, as in all other counties in the state. However, in general, the depth is greater than in the counties to the west and south. There are swamps aggregating more than 100 square miles in area over which the peat will average at least 7 feet thick. Numerous localities were found where the peat is more than 12 feet thick, and the deepest bog discovered in the entire state lies in this county near Central Lakes, a station on the Duluth, Winnipeg, and Pacific railroad.

The following table[87] gives a list of localities where exceptionally deep peat occurs:

1. Central Lakes Station, on Duluth, Winnipeg, and Pacific railroad. Peat is 60 feet thick in deepest portion of bog. (See Locality 41, page 76.)
2. At Eagles Nest Lake, mile post 104, on Duluth and Iron Range railroad. Peat is 17 feet deep.
3. Near McKinley depot, ¼ mile north of mile post Z-1. Duluth and Iron Range railroad. Soundings 18 feet deep.
4. Near McKinley depot. 6 miles north of mile post Z-1. Duluth and Iron Range railroad. Peat is 14 feet deep.
5. Near McKinley depot. 5 miles north of mile post Z-2. Duluth and Iron Range railroad. Soundings 25 feet.
6. Near Pettit station. 7 miles north of mile post Z-2. Duluth and Iron Range railroad. Soundings 30 feet.
7. Near Pettit station. 5 miles north of mile post Z-3. Duluth and Iron Range railroad. Soundings 45 feet.

Not all of the 1,192,160 acres of swamp land in St. Louis County contain workable peat, but fully three fourths of that area is covered by peat of an average depth of 5 feet and probably half of the total

[87] All of this data, except the Central Lakes bog, was supplied through the courtesy of Mr. W. A. Clark, Chief Engineer for the Duluth and Iron Range Railroad Company.

swamp area contains peat which will average at least 7 feet thick. Much of this peat land is so heavily timbered and the peat is so full of buried roots, stumps, and logs, that it could never be used for the manufacture of machine peat. On the other hand, there are hundreds of square miles of swamps, which contain peat of excellent quality for fuel, or other uses. Taking the conservative figure of 596,080 acres, one half of the total swamp area, over which the peat is at least 7 feet thick, there would be available in St. Louis County 834,512,000 tons of air-dry machine peat.

St. Louis County has taken a leading part in reclaiming its peat lands and in experimenting with the agricultural possibilities of peat soils. Already, farming on peat land in St. Louis County has passed the experimental stage, and some of the finest farms in the state, notably the Hartley Farms at Island and Duluth, and the Demonstration Farms of the Duluth and Iron Range Railroad Company at Meadowlands, are located on muskeg land where the peat is from 5 to 25 feet deep. The soil has been found to be admirably adapted to the growth of head lettuce, celery, and other garden vegetables, and at Island Mr. Hartley is raising small grains and hay. In the following pages, detailed descriptions of the most important bogs in the county are given.

CANYON

Locality 1.—This is the eastern edge of the largest muskeg swamp in St. Louis County, which extends westward across 5 townships for 30 miles. This swamp covers approximately 900 square miles, but this includes numerous areas of dry land which occur within the boundaries of the swamp in islands, or as long, narrow tracts along water courses. Because of the great size of the swamp and the variable character of the peat, each place where sampled is described as a separate bog, and a separate locality number has been given to each sample. The portion of the swamp described under this locality number lies in secs. 2, 3, 10, 11, 14, 15, 22, 23, 26, and 27, T. 53N., R. 17W. near Canyon post office on the "Miller Trunk" road.

The vegetation here consists of tamarack and spruce timber with heath shrubs, blueberry, and sphagnum. The peat is underlain by clean bluish gray sand, which rests upon clay. The deposit has been built on a wet, undrained, flat surface which was originally dotted with small lakes and ponds. The deeper portions of the big peat swamp represent these peat-filled lakes and ponds.

The average thickness of the peat at this portion of the swamp is about 7 feet, but the thickness varies from 1 or 2 feet to 24 feet. There is an area of at least 640 acres at this locality over which the peat is at least 20 feet deep. (See hole 13.) Test holes were located along the "Miller Trunk" Road as follows:

Hole 1—¼ mile south of cor. secs. 22, 23, 26, and 27 T. 53N., R. 17W.; thickness 6 feet. South edge of bog.
Hole 2—Corner secs. 22, 23, 26, and 27, T. 53N., R. 17W.; thickness 3 feet.
Hole 3—¼ mile north of No. 2; thickness 2 feet.
Hole 4—¼ corner, on line between secs. 22 and 23, ¼ mile north of No. 3; thickness 2 feet.
Hole 5—¼ mile north of hole No. 4; no peat. On an island in the bog.
Hole 6—Corner of secs. 14, 15, 22, and 23; no peat. On an island in the bog.
Hole 7—¼ mile north of hole No. 6; thickness 3 feet.
Hole 8—¼ mile north of hole No. 7; no peat. On an island in the bog.
Hole 9—¼ mile north of hole No. 8; thickness 7 feet.
Hole 10—Corner secs. 10, 11, 14, and 15; no peat. Black muck.
Hole 11—¼ mile north of hole No. 10; thickness 2½ feet. Undecomposed peat.
Hole 12—¼ mile north of hole No. 11; no peat. On an island. Center of bog.
Hole 13—¼ mile north of hole No. 12; thickness 24 feet. Excellent fine-grained peat.
Hole 14—Corner of secs. 2, 3, 10, and 11; no peat. At edge of an island.
Hole 15—¼ mile north of hole No. 14; no peat. Dry land between holes 14 and 15.
Hole 16—¼ mile north of hole No. 15; thickness 1 foot. Center of large shallow muskeg.
Hole 17—¼ mile north of hole No. 16; thickness 5 feet. Well decomposed peat.
Hole 18—Corner secs. 35 and 36, T. 54N., R. 17W. and secs. 2 and 3, T. 53N., R. 17W.; thickness 12 feet. Well decomposed peat. Blue sandy-clay bottom.
Hole 19—¼ mile north of hole No. 17; no peat. About 40 feet beyond north edge of bog.

Analysis 180 (page 79) represents a composite of the samples obtained from all of the holes described above. The ash content appears rather high for good fuel but if the peat from the vicinity of hole No. 13 were used alone, the per cent of ash would be considerably lower. Moreover, hole No. 13 represents the deepest portion of the bog where the best fuel peat occurs. The region is too remote from a railroad at present to be of value. The nearest point accessible on the railroad is at Birch, a station on the Duluth, Missabe, and Northern railroad, about 6 miles west of the "Miller Trunk" road. This big peat swamp is so variable in character that separate samples should be taken from each square mile before any definite attempt is made to utilize the deposit for peat fuel or other purposes. Many of the samples described in the following pages of this report represent different localities within this great swamp. During the field investigations covering this enormous peat-covered area, separate samples were usually taken for each mile of test holes.

DULUTH

Locality 2.—Farm of Mr. G. G. Hartley, in Duluth, near Woodland Park. Originally this bog was a typical muskeg but the land has been cleared, the surface smoothed, and 70 acres were planted in head lettuce at the time of making the examination. The bog represents a filled lake over which successive layers of plant remains, chiefly sphagnum, have built up the surface 12 to 14 feet above the old lake level.

The peat is from 12 to 20 feet thick, with an average thickness of perhaps 15 feet. It is dark brown and rather fibrous in the upper 15 feet of the deposit. Below this depth the peat is thoroughly decomposed, fine grained, and of a greenish to yellowish color. Sphagnum and heath remains, with numerous pieces of tamarack wood, predominate in the upper portion of the deposit. The lower layers are composed largely of the remains of sedges, pondweeds, and other aquatic plants. There are numerous buried roots and stumps in the upper 4 feet. Samples were taken every 2 feet from top to bottom of the peat from each of 3 holes on a line across the center of the bog, and these were mixed together to obtain a composite sample.

Analysis 181 (page 79) which represents this sample, shows it to contain over 30 per cent of ash which is too high for good fuel peat. The land, however, is much more valuable for growing truck garden produce, especially lettuce and celery, than as a source of peat fuel. The high ash content is due to the inclusion of samples of the greenish pond peat at the bottom of the deposit. By eliminating this pond peat from the sample and including only the material from the upper 15 feet of the deposit, it is probable that the ash content will not run over 12 per cent. The amount of nitrogen present in the peat is unusually high (2.01 per cent) and indicates the high fertility of the peat soil.

Locality 213.—Typical muskeg 10 miles north of Duluth, secs. 3, 9, 10, and 11, T. 51N., R. 15W.; northwest of Wild Rice Lake. The vegetation consists chiefly of small spruce and tamarack trees, very large sphagnum moss, heath shrubs (Labrador tea), sedges, and a little cotton-grass. The bog contains about 640 acres of good peat. The average thickness of the peat as indicated by test holes, is about 7 feet. It is brown, well decomposed, structureless, and plastic, and is made up chiefly of the remains of sphagnum and sedges. Test holes were located as follows:

Hole 1—Corner secs. 2, 3, 10, and 11; T. 51N., R. 15W.; thickness 4 feet.
Hole 2—¼ mile west of No. 1; thickness 8 feet.
Hole 3—¼ mile west of No. 2; thickness 7 feet.
Hole 4—¼ mile west of No. 3; thickness 6 feet.
Hole 5—¼ mile west of No. 4; (near margin); thickness 3 feet.

Analysis 182 (page 79) represents this bog. The peat is of good quality for fuel, and clearing would not be expensive. An old logging road extends along the east margin of the bog, and there are several corduroy wagon roads crossing the bog.

MEADOWLANDS

Locality 4.—This is a portion of a large peat swamp covering many square miles. The village of Meadowlands is situated on a large island of dry land within this big swamp. The area sampled lies about ½ mile northwest of Meadowlands station on the road to the Demonstration Farm of the Duluth and Iron Range railroad. The thickness of the peat at this point is only 3 feet. It is dark brown, fibrous, woody peat which gives an acid test. Originally the swamp was forested with tamarack and spruce, but the timber has been cut and the land cleared, but now it is covered with sedges, grasses, and weeds. No samples were taken from this locality because of the shallowness of the peat. The land immediately adjoining this locality described under localities 5 and 6 contains deeper peat.

Locality 5.—Meadowlands Demonstration Farm of the Duluth and Iron Range Railroad Company; one mile northwest of Meadowlands station on the Duluth, Missabe, and Northern railroad. This was originally a typical muskeg of the built-up type containing many islands of dry land suitable for farming. The vegetation was originally that of a typical muskeg, but much of the area has recently been cleared, and many productive farms are being developed. The peat is underlain by sandy clay. Only a small field of about 10 acres was sampled. This represents only a small portion of a big bog which covers many square miles in this region. The average thickness of the peat here is only 2½ feet, but the thickness rapidly increases to the east of the field where the samples were taken.

Fourteen test holes were put down in the 10-acre field, and a composite sample was obtained. Analysis 183 (page 79) represents this sample.

Locality 7.—Another portion of the bog described above under Locality 5. This locality is ½ mile south and ½ mile west of Meadowlands station along the drainage ditch which extends east and west across the center of sec. 22. The original vegetation was tamaracks, spruce, heath, and sphagnum. The land has been recently cleared, and is now planted with hay, of which there was an excellent crop at the time of visit. The peat is underlain by fine-grained, marly clay. The bottom of the bog is flat and smooth.

The thickness of the peat at this point is only 2 to 3 feet. It is dark brown, fibrous peat, composed chiefly of sphagnum moss, and containing much woody material. A composite sample was collected from numerous points along the ditch across the center of sec. 22. No test holes were necessary for the peat is exposed from top to bottom, in the sides of the ditch.

Analysis 184 (page 79) represents this peat, and shows the ash to be higher than the average. Because of its high ash content, and the shallowness of the peat, it is doubtful if this locality could supply good peat fuel.

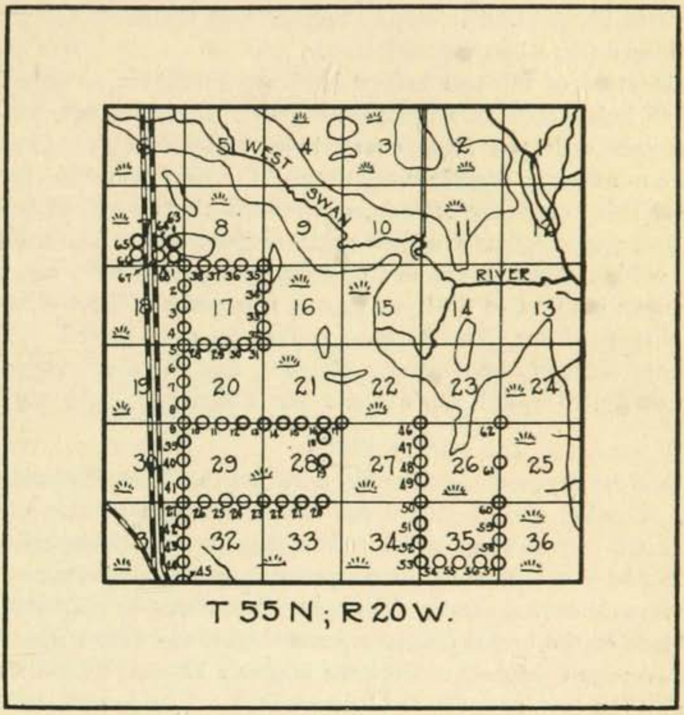

FIGURE 8. MAP OF T. 55N., R. 20W., SHOWING LOCATION OF TEST HOLES WHERE SAMPLES WERE TAKEN

Locality 6.—This sample is a composite from 68 test holes in T. 55N., R. 20W., as shown in Figure 8. The vegetation of this big swamp consists chiefly of tamarack, spruce, sphagnum, and heaths. Secs. 7, 17, 18, 19, 20, 21, 28, 29, and 30 are timbered with small tamarack which will run about 3 cords of lagging to the acre. Secs. 32 and 33 have a good strip of tamarack timber, which will run about 5 cords of lagging to the acre. Secs. 22, 23, 24, 25, 26, 27, and 35 are mostly timbered with spruce. The living moss on these sections is much deeper than that in the tamarack timber.

The peat is underlain by blue clay, and the bottom of the bog is nearly flat, indicating that the deposit has been built up on a drained surface. This township contains about 26 square miles of peat bog, and 10 square miles of dry land. The dry ground lies in the three northern rows of sections. The area is a portion of the great St. Louis County swamp which covers nearly 900 square miles. The average thickness of the peat in this township as shown by 68 widely scattered test holes, is about 10 feet. The peat is shallower in those portions of the bog timbered with spruce. The peat is mostly brown in color, and fibrous and woody in texture, but the lower portion of the deposit shows more decomposition.

The location of the test holes[88] is shown in Figure 8, page 225. A total of 68 holes, most of which were spaced ¼ mile apart, were sunk, samples were collected from every hole, and all mixed. From this mixture an average sample was obtained. Analysis 185 (page 79) represents this composite sample, and shows that the peat is of good quality and would make excellent machine peat fuel. The ash content is not too high and the amount of fixed carbon is above the average. The nitrogen content of 2.04 per cent is also noteworthy. The land in this locality produces grass as soon as drained and cleared. The Hull-Rust Short Line of the Duluth, Missabe, and Northern railroad runs north and south through the western tier of sections in the township.

ELMER

Locality 8.—Typical muskeg 1¼ miles north of Elmer station on the Duluth, Missabe, and Northern railroad. This is a portion of the big St. Louis County swamp, which covers nearly 900 square miles. The vegetation here consists chiefly of spruce, tamarack, blueberry, heaths, sphagnum, and cotton-grass. The peat is underlain by plastic blue clay. The bottom of the bog is rather uneven with many minor irregularities.

The average thickness of the peat is about 12 feet, with a maximum thickness of 17 feet, as indicated by test holes. The peat is dark brown, and well decomposed, except in the upper 3 or 4 feet of the deposit where it is more fibrous. Many roots and pieces of wood are buried in the peat, some of these occurring as deep as 10 feet below the surface. The peat is made up chiefly of the remains of sphagnum moss, heath shrubs, and wood fibre.

The location of the test holes is as follows:

Hole 1—1¼ miles north of Elmer station, at east edge of railroad track. Peat 7 feet deep, of a dark brown color, well decomposed. Blue plastic clay bottom.

Hole 2—¼ mile northwest of No. 1. At east edge of track. Peat 17 feet deep, and well decomposed. Sandy bottom.

Hole 3—¼ mile northwest of No. 2. At east side of track. Peat 17 feet deep, and well decomposed. Sandy clay bottom.

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[88] The soundings given herewith were made by the Land Department of the Duluth and Iron Range railroad and the data were supplied through the courtesy of Mr. L. B. Arnold, Land Commissioner for the Duluth and Iron Range Railroad Company, Duluth, Minnesota.

Hole 4—¼ mile northwest of No. 3. At east side of track. Peat 12+ feet deep. Could not reach bottom on account of mat of logs and roots at 12 feet, which could not be penetrated by the sampling instrument. Large quantities of water standing on surface of bog at this point.

Hole 5—¼ mile northwest of No. 4. East side of track. Peat 10+ feet deep. Could not reach bottom with the sampler on account of logs and roots 10 feet below surface. Peat well decomposed.

Hole 6—¼ mile northwest of No. 5, and 50 feet from an island in the bog. Peat 6 feet deep. There are fewer trees in this part of the bog, and more sedges and heaths. The island is about ¼ mile wide at this point.

Analysis 186 (page 79) shows the composition of the peat from this part of the swamp. The thermal value is high, and the ash content low, which indicates an excellent fuel peat. This bog could be easily developed for the manufacture of machine peat, and a large quantity of excellent material is available on both sides of the Duluth, Missabe, and Northern railroad tracks.

FLOODWOOD

Locality 10.—Muskeg 1 mile northwest of Floodwood station along Great Northern railroad tracks, sec. 36, T. 52N., R. 21W. The vegetation on the bog consists chiefly of spruce, tamarack, sedges, sphagnum, heaths, and grasses. The peat has accumulated on an undrained surface and represents a built-up deposit.

This represents the east edge of a big swamp which extends west, north, and south for many miles. Along the east edge of this swamp there is a strip about 1 to 1½ miles wide where the peat is only 1 to 3 feet deep. This sample represents this shallow strip. The peat is brown, fibrous, and woody, and is made up mostly of sphagnum with many roots, sticks, etc.

No test holes were necessary as the peat is continuously exposed on the sides of a drainage ditch along the railroad. Samples were gathered from the sides of this ditch every ¼ mile, beginning 1 mile northwest of Floodwood, and continuing for 2 miles along the track. An island three fourths of a mile across lies between these points. All the samples were mixed.

Analysis 188 (page 79) represents this peat. The land if cleared and drained could probably be used for agricultural purposes, since the peat is so shallow that the soil could be reached with a deep tiller.

MESABA

Locality 12.—Muskeg swamp at Graham Iron Mine, Mesaba station. The vegetation consists of spruce, tamarack, heaths, and sphagnum. The bog is a typical muskeg, built up on a rather flat surface. The peat is underlain by about 25 feet of glacial drift, which in turn is underlain by iron ore. (See Figure 9.) There are about 640 acres of peat-land here. The peat varies in thickness from 6 to 14 feet, with an average of about 10 feet. It is dark brown, very fibrous, with many roots and stems. The lower 2 feet of the deposit is black and decomposed. Sphagnum moss with the remains of heaths, make up the peat. The open pit of the Graham mine lies near the center of the bog. This pit is roughly circular in plan, and the entire thickness of the peat is exposed around the edge of the open pit. Samples were taken from the top to the bottom of the peat at 100-foot intervals around the edge of the pit, and were all mixed for an average.

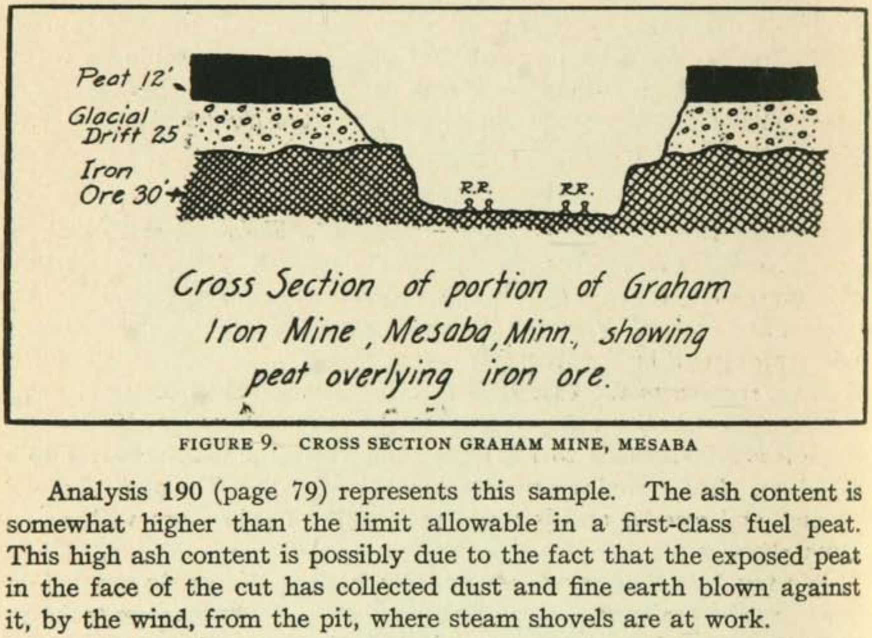

FIGURE 9. CROSS SECTION GRAHAM MINE, MESABA

Analysis 190 (page 79) represents this sample. The ash content is somewhat higher than the limit allowable in a first-class fuel peat. This high ash content is possibly due to the fact that the exposed peat in the face of the cut has collected dust and fine earth blown against it, by the wind, from the pit, where steam shovels are at work.

WALLACE

Locality 9.—Muskeg swamp 1½ miles north of Wallace station, on the Duluth, Missabe, and Northern railroad. This is a part of the large St. Louis County swamp, referred to in the preceding paragraphs. The vegetation on the bog consists of a thick growth of scrub tamarack, with sphagnum moss and heath shrubs well developed. In places the trees have died out, and sedges are crowding out the other plants. The peat is underlain by sandy clay.

There are about 30 square miles of peat in this township. The remaining 6 square miles in the township consist of dry land which occurs as numerous islands in the swamp. The average thickness of the peat at this locality is 7½ feet. The upper portion of the deposit is fibrous, dark brown material, while the lower layers are made up of light brown, decomposed, rather fluid peat. The entire mass is full of woody fibre, sticks, and roots. Sphagnum moss is the most important peat-forming plant. The occurrence of a heavy layer of buried logs and roots indicates that a forest of tamarack and spruce existed at an early period in the history of the bog.

Test holes were located at ¼ mile intervals along a line beginning 1½ miles north of Wallace, and extending southward along the railroad tracks as follows:

Hole 1—Peat 10+ feet deep. Could not reach bottom. Attempts were made to push the sampler down to the bottom in 12 different places around this point, but in every attempt logs or stumps of buried trees were encountered at a depth of 10 feet. Upper 4 feet the peat is dark brown, mossy and fibrous. Below 4 feet, the peat is light brown, well decomposed, and of even texture.

Hole 2—Dark brown, fibrous peat, 6 feet. Blue sandy clay bottom.

Hole 3—Dark brown, firm, fibrous peat, 6 feet. Sandy blue clay bottom. 1 foot black muck above bottom.

Hole 4—Dark brown, firm, fibrous peat, 7 feet.

Hole 5—250 feet northwest of No. 4 at junction of lateral east-west ditch, with main ditch along railroad. Peat 6 feet thick, and rather fibrous. Sandy clay bottom.

Hole 6—¼ mile northwest of No. 4. Dark brown, firm, fibrous peat, 7 feet. Sandy bottom.

Hole 7—Dark brown, firm, fibrous peat, 6 feet. Heavy tamarack timber.

Analysis 187 (page 79) shows the composition of the peat. The ash is low and the thermal value is high, indicating a good fuel peat. The bog extends northward from hole No. 7 for at least 1½ miles, and southward from hole No. 1 for an equal distance, but the peat becomes shallower as the edge of the bog is approached.

Localities 18 to 24.—Typical muskeg or tamarack-spruce swamp of the built-up type extending from Wallace to Zim, a distance of 7 miles along the Duluth, Missabe, and Northern railroad, about 50 miles north of Duluth. The muskeg is a portion of the big St. Louis County swamp. The vegetation consists chiefly of tamarack, spruce, sphagnum, heaths, blueberry, cranberry, sedges, bulrushes, grasses, swamp ferns, and a few swamp alders in places. Sphagnum is dominant. The peat is underlain by sandy blue or yellowish clay.

The peat varies in depth from 4½ feet near the edge of the bog to a maximum of 9 feet near the center. The average depth for the entire distance of 7 miles across the bog is approximately 8 feet. The peat is dark brown, rather fibrous on top to well decomposed below. It is somewhat fluid in the lower portion of the deposit. Numerous roots and logs were encountered in sinking test holes. The peat gives an acid test. A faint odor of hydrogen-sulphide was noticeable in some of the test holes. The peat is composed mostly of sphagnum moss from top to bottom.

Test holes were put down at one mile intervals along the railroad from Wallace to Zim, a distance of 7 miles. Samples were taken from each test hole and separate locality numbers were given to each of these samples which were analyzed separately. The exact locations of the 7 test holes which were put down along the railroad across this bog, together with brief notes on the depth of the peat at each locality, are given as follows:

Locality 18.—At Wallace railroad station, T. 55N., R. 18W. NE¼ of NE¼ sec. 34. Depth of peat is 8 feet. Analysis 191 (page 79) represents this sample.

Locality 19.—At mile post 50, north of Wallace, along Duluth, Missabe, and Northern railroad track. Depth of peat 6 feet. Analysis 192 (page 80) represents this sample.

Locality 20.—At mile post 51, north of Wallace, on Duluth, Missabe, and Northern railroad. Depth 9 feet. Analysis 193 (page 80) represents this sample.

Locality 21.—At mile post 52, north of Wallace, on Duluth, Missabe, and Northern railroad. Depth of peat 7 feet. Analysis 194 (page 80) represents this sample.

Locality 21a.—At mile post 53, north of Wallace, on Duluth, Missabe, and Northern railroad. Depth of peat 7 feet. Analysis 195 (page 80) represents this sample.

Locality 22.—At mile post 54, north of Wallace, along Duluth, Missabe, and Northern railroad. Depth of peat 6 feet. Analysis 196 (page 80) represents this sample.

Locality 23.—At mile post 55, north of Wallace, along Duluth, Missabe, and Northern railroad. Depth of peat 5 feet. Analysis 197 (page 80) represents this sample.

Locality 24.—At mile post 55¼, north of Wallace, along Duluth, Missabe, and Northern railroad. Depth of peat 5 feet. Analysis 198 (page 80) represents this sample.

The analyses from these holes (analyses nos. 191 to 198 inclusive, pages 79 and 80) show the peat in this portion of the swamp to be remarkably uniform in composition. Over a distance of 7 miles the analyses show but very slight variation. The thermal value of each sample is high, and the ash content is very low. The nitrogen is unusually high, and the amount is practically the same in all of the eight samples.

This locality offers exceptionally favorable conditions for the establishment of a machine peat plant. The high quality of the peat, the uniformity of texture and composition, the large quantity available, and the proximity to the railroad, indicate the possibilities for development.

The only serious disadvantage which the area possesses is the heavy growth of small spruce and tamarack timber on some portions of the bog, which would necessitate a large expense for clearing.

Locality 52.—Muskeg 1¼ miles north of Wallace on the Duluth, Missabe, and Northern railroad. Tamarack, spruce, sphagnum, heath shrubs, sedges, grasses, and bulrushes make up the vegetation of this bog. The peat is underlain by clayey glacial till and the bog is of the built-up or high-moor type.

This is a portion of the great St. Louis County swamp and contains many square miles. The peat at this place is 7 feet thick. It is dark brown, rather fibrous, but more decomposed near the bottom. It is made up chiefly of sphagnum and contains many small roots of heath shrubs, and some large pieces of wood.

A sample of 1 ton of peat was taken at this point, and from this an average sample was obtained for analysis.

Analysis 225 (page 80) represents this sample. The ash content is low (13.15 per cent) and the nitrogen is high (2.42 per cent). This locality is well situated for the development of a peat fuel plant, and the peat is of excellent quality for the manufacture of machine peat.

Locality 53.—This represents another portion of the same bog just described in the preceding paragraph. A test hole was put down 1 mile north of Wallace along the Duluth, Missabe, and Northern railroad in sec. 27, T. 55N., R. 18W. The peat here is 7 feet thick, and is similar in texture and composition to the peat in other portions of the bog.

Analysis 226 (page 80) which represents this sample, shows it to be almost identical in composition with that from Locality 52.

TOIVOLA

Localities 25 to 39.—These samples were taken at every mile post along the Duluth, Missabe, and Northern railroad between Elmer station (on the Coleraine branch) and a point 8 miles north of Hull on the Hull-Rust cut-off. This is a distance of 14 miles, and the peat extends continuously for the entire distance, with the exception of an island just north of Bunker Siding. Each of the 15 samples taken across this big swamp was given a separate locality number, and a separate analysis was made of each sample.

The vegetation consists chiefly of tamarack, spruce, cedar, sphagnum, heaths, sedges, grasses, bulrushes, blueberry, cranberry, and swamp ferns.

The peat is underlain by glacial drift consisting of sand, or clay, or mixtures of these. The deposit rests upon a comparatively flat and smooth surface, free from depressions and irregularities, which probably represents an old glacial outwash plain. The peat deposit has been built up on this flat undrained surface, and is of the high-moor type. The entire St. Louis County swamp which covers nearly 900 square miles is a built-up deposit although within this immense swamp are numerous filled-lake bogs. The average thickness of the peat for a distance of 14 miles across the bog is about 8 feet. The thickness however, varies from 3 to 13 feet, the lower figure representing the peat near the edge of the bog.

The color of the peat varies from brown to black, according to depth, the lower layers showing darker shades of color. The texture of the peat varies from fibrous material in the upper layers to well decomposed peat in the central and lower portions of the deposit. The peat is rather firm near the surface, but becomes more fluid with depth, although in none of the test holes was it too fluid to obtain a core in the sample. The peat gave an acid test with litmus paper. Marsh gas was noticed at some of the test holes. Sphagnum moss has been the chief peat-forming plant in this swamp.

A test hole was put down at every mile post along the Duluth, Missabe, and Northern railroad, beginning at mile post No. 9 on the Hull branch, and extending to mile post 16 on the Coleraine branch. Each hole was given a separate locality number, and a separate sample was collected from each and analyzed separately.

The locations of the 15 test holes included in this description, with notes on the depth and character of the peat, and type of vegetation, etc., are as follows:

Locality 25.—At mile post No. 9, on Hull-Rust branch of Duluth, Missabe, and Northern railroad, T. 56N., R. 20W., NE¼ of NW¼ sec. 19. Depth of peat 5½ feet. Spruce and tamarack 8 to 12 inches in diameter. Analysis 199 (page 80) represents this sample.

Locality 26.—At mile post No. 8 Hull-Rust branch of Duluth, Missabe, and Northern railroad. Depth of peat 10½ feet. Gray sand bottom; 3- to 4-inch tamarack. Analysis 200 (page 80) represents this sample.

Locality 27.—At mile post No. 7. Hull-Rust branch, Duluth, Missabe, and Northern railroad. Depth of peat 5 feet (near edge of island). Gray sand bottom. Dark brown to black, plastic peat; 3- to 4-inch tamarack. Analysis 201 (page 80) represents this sample.

Locality 28.—At mile post No. 5. Hull-Rust branch, Duluth, Missabe, and Northern railroad. Depth of peat 5 feet. Yellow clay bottom. Black to dark brown, decomposed peat. Tamarack timber. Analysis 202 (page 80) represents this sample.

Locality 29.—At mile post No. 4, Hull-Rust branch, Duluth, Missabe and Northern railroad. Peat 9½ feet thick. Gray sand bottom. Bog is more open here. Analysis 203 (page 80) represents this sample.

Locality 30.—At mile post No. 3, Hull-Rust branch, Duluth, Missabe, and Northern railroad. Peat 9½ feet thick. Gray sand bottom. Rather heavy growth of 2- to 4-inch tamarack. Analysis 204 (page 80) represents this sample.

Locality 31.—At mile post No. 2, Hull-Rust branch, Duluth, Missabe, and Northern railroad. Peat 8 feet thick. Gray sand bottom. Peat is dark brown, plastic, and well decomposed. Vegetation: 2- to 4-inch tamarack, and a heavy growth of grasses and sedges. Analysis 205 (page 80) represents this sample.

Locality 32.—At mile post No. 1, Hull-Rust branch, Duluth, Missabe, and Northern railroad. Peat 6 feet thick; dark brown, fibrous, and rather fluid. Blue clayey-sand bottom. Vegetation: 2- to 3-inch tamarack, with much grass. Analysis 206 (page 80) represents this sample.

Locality 33.—At Hull Junction, on Duluth, Missabe, and Northern railroad across track from section house. Peat 7 feet thick. Gray sand bottom; 6-inch tamarack timber on the bog. Analysis 207 (page 80) represents this sample.

Locality 34.—At mile post No. 22, Coleraine line; Duluth, Missabe and Northern railroad. Peat 13 feet thick. Gray sand bottom. Heavy growth of 4- to 8-inch tamarack. Analysis 208 (page 80) represents this sample.

Locality 35.—At mile post No. 21, Coleraine line, Duluth, Missabe, and Northern railroad. Peat 5 feet thick. Blue sandy clay bottom. Vegetation: 4- to 6-inch tamarack. Analysis 209 (page 80) represents this sample.

Locality 36.—At mile post No. 19, Coleraine line, Duluth, Missabe, and Northern railroad. Dark brown, fibrous, mossy peat; 7 feet. Blue sand bottom. Bog is rather open; few 2-inch tamaracks. Analysis 210 (page 80) represents this sample.

Locality 37.—At mile post No. 18, Coleraine line, Duluth, Missabe, and Northern railroad. Peat 3 feet deep, near island. Bog is much deeper (8-10 feet) 1,000 feet south of this hole. Gray sand bottom. Edge of an open bog of about 640 acres. Analysis 211 (page 80) represents this sample.

Locality 38.—At mile post No. 17, Coleraine line, Duluth, Missabe, and Northern railroad. Peat 11 feet thick. Brown, fibrous peat, with grass and heath remains; 2- to 4-inch spruce. Analysis 212 (page 80) represents this sample.

Locality 39.—At mile post No. 16, Coleraine line, Duluth, Missabe, and Northern railroad. Peat 9½ feet thick. Blue clay bottom. Scattered scrub spruce. Bog is open. Analysis 213 (page 80) represents this sample.

The analyses of the 15 samples from this big muskeg swamp (analyses 199-213) show that the peat possesses remarkable uniformity of composition for such a large area. The peat has a thermal value, as shown by these analyses, which will average about 10,000 B.T.U. per pound, calculated on a moisture and ash free basis. The ash content averages only 12.59 per cent which is low for American peats. The average amount of nitrogen present as shown by the 15 samples is about 2.5 per cent. The peat compares favorably with peat from any part of the world as a source of fuel, or as a source of nitrates for fertilizer.

CENTRAL LAKES

Locality 40.—Peat-filled pond at mile post 57 near Central Lakes station on the Duluth, Winnipeg, and Pacific railroad. The vegetation on the bog consists of sphagnum moss, sedges, grasses, ferns, and spruce timber.

This locality represents a small arm of an immense bog which extends for many miles to the west, and which is the northeastern portion of the big St. Louis County swamp. The thickness of the peat where this sample was taken is 17 feet. It consists of brown, mossy, fibrous peat throughout the upper 8 feet of the deposit, below which occurs greenish, soft, plastic pond peat. Only one hole was put down at this locality, since this part of the bog is too small to be of commercial value as a source of fuel.

Analysis 214 (page 80) which represents this sample, shows the ash content to be too high for good fuel peat. This is due to the fact that the green pond peat from the lower portion of the deposit was included in the sample for analysis. The top 8 feet of sphagnum peat will show a much lower ash content.

Locality 41.—Muskeg near Central Lakes station, on the Duluth, Winnipeg, and Pacific railroad. This muskeg represents a filled lake which has been built up to a height of about 14 feet above the old water level by successive layers of moss peat. The peat is underlain by blue clay, and the bog is surrounded by hills of glacial drift. Tamarack, sphagnum, heath shrubs, sedges, and grasses, are the predominating plants on the bog.

The area of the muskeg includes many square miles. This part of the bog is crossed by the tracks of the Duluth, Winnipeg, and Pacific railroad, and the peat deposit here is the deepest found in the state. The maximum depth of the bog is 63 feet.[89] The accompanying topographic map (see Figure 10) of the bottom of the bog with a cross

[89] Depth determined by the Engineering Department of the Duluth, Winnipeg, and Pacific railroad.

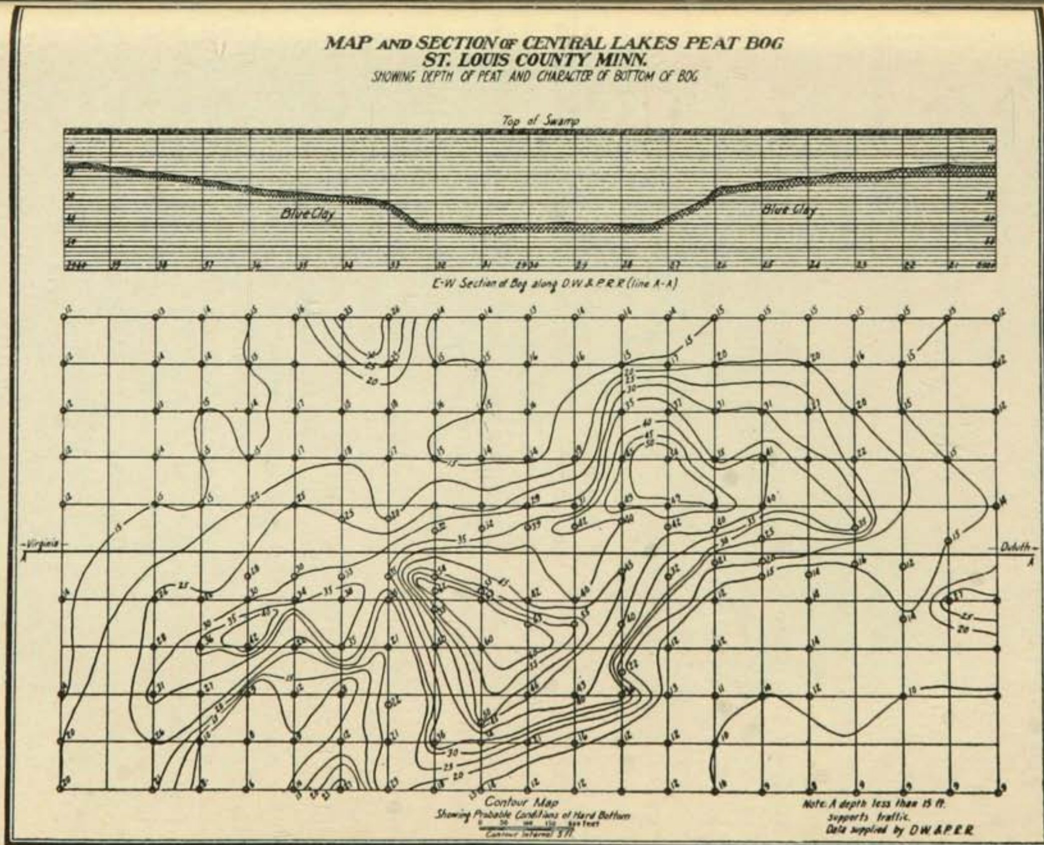

FIGURE 10. MAP AND SECTION OF CENTRAL LAKES BOG

section along the railroad, shows the variation in thickness of this deposit and the location of the test holes.

The upper 14 feet of the peat consists of brown, mossy sphagnum peat, and below this depth the peat is typical soft, plastic, green pond peat. The lower portion of the peat is very fluid and the peat is underlain by water, indicating that the original lake has not been completely filled.

Only one hole was put down by the writer to secure a sample, since the bog had been sounded by the railroad company as shown in Figure 10. Two samples were taken from this test hole, one representing the upper 14 feet of mossy peat, and the other representing the typical green pond peat below a depth of 14 feet.

Analysis 216 (page 80) represents the upper portion of the deposit, and analysis 215 (page 80) represents green pond peat in the lower portion of the bog. Comparison of these analyses shows that the deeper pond peat contains 23.9 per cent ash, while the sphagnum from the upper layers contains only 10.07 per cent. This illustrates a condition which always exists in peat bogs which have been formed by the filling of lakes with peat from aquatic plants, and subsequent building up of the deposit above the lake level by sphagnum peat. The pond peat seems to be always mixed with more or less marl and silt, and the plant remains from which it is formed also contain a higher proportion of inorganic mineral matter than does sphagnum moss. Another noteworthy fact is the high nitrogen content of the pond peat, 2.62 per cent compared with moss peat, 1.8 per cent. Many of the deposits of sphagnum peat in Minnesota contain a considerably higher proportion of nitrogen than is shown by this analysis. The pond peat does not always contain more nitrogen than the fibrous moss and sedge-peat.

This bog has caused the railroad company much trouble due to the constant sinking of the gravel fill upon which the tracks are laid. The amount of subsidence of the road bed is shown in the profile Figure 10. Apparently this bog is covered by an unusually thick floating peat mat, and unless the surrounding portions of the bog are drained, there is a possibility that the heavy gravel fill may break through the floating peat mat and disappear beneath the bog.

HULL JUNCTION

Locality 44.—Muskeg in T. 55N., R. 20W. along Hull-Rust cut-off on the Duluth, Missabe, and Northern railroad. The vegetation throughout this muskeg consists chiefly of tamarack, spruce, sphagnum, heaths, and sedges. The peat is underlain by clay and sand. The muskeg is a built-up deposit of the high-moor type.

This big peat swamp covers the greater part of the township and extends into the surrounding townships. It represents a part of the great St. Louis County muskeg swamp, which covers nearly 900 square miles. At this locality the average thickness of the peat is 7 feet. The peat, which is fibrous, is composed almost entirely of sphagnum moss. It is brown in color. A test hole was put down at the corner of secs. 23, 24, 25, and 26, and a composite sample was taken from top to bottom of the peat.

Analysis 217 (page 80) shows the ash content to be only 5.77 per cent. There are few peat deposits in the world which have a lower ash content than this. The peat will make excellent fuel, and the bog is well situated for development.

Locality 45.—This represents another portion of the muskeg just described under Locality 44. The peat here is 13½ feet thick, and consists of brown, mossy, fibrous material. A test hole was put down at the corner of secs. 19, 20, 29, and 30. A composite sample was taken. Analysis 218 (page 80) shows the composition of the peat from this test hole. It is of excellent quality for the manufacture of peat fuel, and the nitrogen content is very high.

Locality 46.—This represents another portion of the muskeg described under Locality 44. This sample was taken at the corner of secs. 7, 8, 17, and 18. The peat is 7½ feet thick, and consists of brown, mossy, fibrous material. Analysis 219 (page 80) represents this sample.

Locality 47.—This is also another portion of the same muskeg as that described under Locality 44. A test hole was put down at the corner of secs. 17, 18, 19, and 20, and a composite sample was taken from top to bottom of the deposit. The peat is 13½ feet thick at this locality. It is made up of fibrous, woody, brown peat, composed chiefly of sphagnum moss. Analysis 220 (page 80) which represents this sample, shows the peat to be very similar in composition to that from other localities in the bog.

Locality 48.—This also is another portion of the same muskeg as that described under Locality 44. A test hole was put down at the corner of secs. 5, 6, 31, and 32, and a composite sample of peat was obtained from the top to the bottom of the deposit. The peat here is 10 feet thick. It is similar in texture and composition to that which occurs in other portions of this township. Analysis 221 (page 80) represents this sample, and shows the ash content very low (8.22 per cent).

Locality 49.—This also represents another portion of the same muskeg as described under Locality 44. A sample was collected from a test hole put down at the corner of secs. 8, 9, 16, and 17. The peat here is only 4¾ feet thick. It is similar in character and composition to that in other portions of the bog. Analysis 222 (page 80) represents this sample.

Locality 50.—This also represents a portion of the muskeg described under Locality 44. A test hole was put down at the corner of secs. 16, 17, 20, and 21, and a composite sample was obtained from top to bottom of the deposit. The peat is 8 feet thick at this point, and consists of brown, fibrous material, chiefly sphagnum moss. Analysis 223 (page 80) which represents this sample, shows the peat to be of good quality for fuel.

Locality 51.—This also represents another portion of the muskeg described under Locality 44. A test hole was put down at the corner of secs. 22, 23, 26, and 27, where the peat was found to be 4½ feet thick. The peat is similar in texture and composition to that in other portions of the bog. Analysis 224 (page 80) represents this sample.

ISLAND

Locality 11.—Muskeg between Floodwood and Island, on the Great Northern railroad, secs. 16, 22, and 26, T. 52N., R. 21W. Spruce, tamaracks, heaths, sphagnum, sedges, and grasses comprise the vegetation on this bog. Near Island the swamp has been cleared, and the ground plowed, and good crops of hay and grain are being raised. The muskeg is a built-up deposit and not a filled lake.

There are many square miles in this bog, which is a part of the great St. Louis County muskeg swamp. Many small islands of dry land occur on the bog, and the station and farm at Island have thus been named because of their situation on one of these islands of higher ground.

The average thickness of the peat along the track is about 10 feet, and the maximum thickness indicated by test holes is 16 feet. The peat is dark brown, firm, and fibrous. It turns darker immediately upon exposure to air. The bottom 2 feet is black and somewhat silty. A rather strong odor of marsh gas was noticeable in some of the test holes. The lower half of the deposit is fairly well decomposed, although pieces of wood were found from top to bottom of the bog. Sphagnum has been the most important peat-forming plant.

Hole No. 1 was sunk 2 miles plus 1,700 feet northwest of Floodwood station along the railroad track. Additional holes were spaced 1,000 feet apart along the railroad to the station at Island as follows:

Hole 1—Thickness 8 feet. Dark brown, firm peat. Clay bottom.
Hole 2—Thickness 6½ feet. Dark brown, firm peat. Clay bottom.
Hole 3—Thickness 7½ feet. Dark brown, firm peat. Clay bottom.
Hole 4—Thickness 8 feet. Dark brown, firm peat. Clay bottom.
Hole 5—Thickness 16 feet. Brown peat, many roots. (In a hay field.)
Hole 6—Thickness 13 feet. Firm, woody peat. Blue sandy clay bottom.
Hole 7—Thickness 13 feet. Firm, woody peat. Blue sandy clay bottom.
Hole 8—Thickness 9 feet. Firm brown peat. Blue sandy clay bottom.

Analysis 189 (page 79) represents the peat here. It shows a high thermal value and low ash content, and the nitrogen content is unusually high. This bog would make a good site for a machine peat fuel plant, but the land has been demonstrated to have a higher value for agricultural purposes. Mr. G. G. Hartley, of Duluth, who owns the Island farm, has converted an area of typical, virgin, muskeg swamp into productive land, in spite of the fact that the peat on some of the area is 16 feet deep.

Locality 116.—This represents an adjoining portion of the bog just described under Locality 11. The muskeg is exceptionally well developed between Island, St. Louis County, and Wawina, Itasca County, both stations on the Great Northern railroad. The vegetation here consists of sphagnum, heath shrubs, scrub tamarack, and scattered spruce. The latter are especially prominent near the edges of the bog. The peat is underlain by fine-grained, clean, bluish sand. The peat deposit evidently represents a filled, shallow lake, and has been built up later by sphagnum peat.

The area of the bog, of which this is a part, includes many square miles. The average thickness of the peat at this place is about 7½ feet. It is dark red-brown in color, fibrous near the top, and well decomposed below. The upper 3 feet is made up chiefly of sphagnum, below which the peat is composed of the remains of sedges and aquatic plants.

Samples were collected between mile posts 83 and 84. The first hole was put down 1¼ miles northwest of Island station, along the Great Northern railroad. The location of the test holes is as follows:

Hole 1—Northwest of Island, at mile post 83¼, Great Northern railroad; thickness 4 feet. Many roots. 1- to 4-inch tamarack and spruce.
Hole 2—At mile post 83½; thickness 8½ feet. Chiefly sedge-peat.
Hole 3—At mile post 83¾; thickness 9 feet. Top 3 feet chiefly moss.

Analysis 227 (page 80) represents this sample. This is one of the largest and best open bogs in the county. From Wawina, Itasca County, to a point 1½ miles west of Floodwood, there is a continuous muskeg, except at Island, which is located on an island of higher ground which occurs in the bog. (See Locality no. 11, page 79.)

Locality 117.—This is a continuation of the Wawina-Island bog, described under Locality 116. The average thickness of the peat at this point in the bog is about 15 feet. A composite sample was taken from test holes located as follows:

Hole 1—At mile post 84; thickness 6½ feet. Only top 6 inches is moss.
Hole 2—At mile post 84¼; thickness 8 feet. Very little moss. Mostly sedge-peat of uniform texture.
Hole 3—At mile post 84½; thickness 16½ feet. Very little moss. Mostly sedge-peat of uniform texture.

Hole 4—At mile post 84¾; thickness 16 feet. Very little moss. Mostly sedge-peat of uniform texture.
Hole 5—At mile post 85; thickness 18 feet. Very little moss. Mostly sedge-peat of uniform texture.

In addition to this composite sample which represents an average of the entire thickness of the peat, a separate sample was taken consisting of only the lower portion of the peat which is composed of sedges and aquatic plant remains.

Analysis 228 (page 80) represents the composite sample of the entire thickness of the peat. Analysis 229 (page 80) represents the pond peat in the lower portion of the deposit. A comparison of these analyses shows the fact already noted in other deposits, that the pond peat contains a higher ash content than the moss peat. The bog presents commercial possibilities not exceeded by any other deposit in Minnesota. It is an excellent, level bog, on which very little preparatory work would be required. The surface is not excessively wet and the area could be easily drained through the big ditches which are already constructed through a portion of the bog. The deepest and best peat in the deposit lies around the extreme northeast corner of Aitkin County where Aitkin, Itasca, and St. Louis counties join. The upper 3 feet of the peat, which consists of pure clean sphagnum moss, very slightly decomposed, would make excellent peat litter or packing.

SCOTT COUNTY

The Minnesota River forms the north and west boundaries of Scott County, and along its valley there are some rather extensive marshes. These marshes contain no pure peat deposits, for much silt is mixed with the plant remains which have accumulated there. In addition to the marshes along the Minnesota River valley, there are some "sloughs" and meadows in nearly every township in the county, but none of these are the sites of peat accumulations of noteworthy extent or depth. The material in most of these marshy areas was found to be black muck.

SHERBURNE COUNTY

Sherburne County, which lies about 40 miles northwest of Minneapolis and St. Paul, is a short distance north of the southern limit of muskeg swamps in Minnesota. There are no large swamps or marshes in Sherburne County, but numerous small sloughs, marshes, and meadows exist, a few of which contain an area of 800 to 1,000 acres. The largest marshes lie north of the town of Elk River, in Elk River and Livonia townships, and there is a rather large marsh in the northern portion of Becker Township. The marshes all contain some peat, but few of them contain important quantities. Some of the peaty areas were originally muskeg swamps, which have been either burned or cleared, and partially drained, so the original vegetation of the bog has disappeared, and only traces of the former character of the deposits are to be seen from the few dead tamarack roots, or stumps, buried in the peat. The areas are now, for the most part, open sedge-grass meadows, with scattered growths of swamp shrubs, or bushes here and there. The peat varies in depth in these deposits from a few inches to 12 to 15 feet. The shallower deposits predominate. In the large meadow, east of St. Cloud, the peat has an average depth of 3 feet. The best fuel peat found in the county occurs about 2 miles north of Elk River, west of Houlton Siding, on the Milaca branch of the Great Northern railroad. This bog, and another smaller one at the edge of the town of Elk River, are described below.

ELK RIVER

Locality 243.—Peat meadow, 2 miles north of Elk River at Houlton Siding on the Milaca branch of the Great Northern railroad. This meadow occupies parts of secs. 8, 9, 16, 17 and 20, T. 33N., R. 26W. The marsh is used as a hay meadow, and sedges and grasses predominate. Near the center of the area there is a quaking bog covered with reed-grass. The peat is underlain by sand.

The bog contains an area of about 500 acres. The northern part of the bog only was tested. The average thickness there was found to be about 8 feet, and the maximum thickness 12 feet. The peat is brown, rather fibrous near the top, and decomposed and gritty near the bottom. The lower layers consist of greenish pond peat. Considerable sand was noted in the lower portion of the peat deposit. The peat is made up chiefly of sedges and reed-grass, with a layer of moss peat at a depth of 8 feet.

Test holes were located along an east-west line through the center of section 17 as follows:

Hole 1—300 feet east of margin of bog; thickness 12 feet.
Hole 2—300 feet east of No. 1; thickness 10 feet.
Hole 3—300 feet east of No. 2; thickness 8 feet.
Hole 4—300 feet east of No. 3; thickness 10 feet.

Analysis 230 (page 80) represents this deposit.

Locality 14.—Bog near the edge of the town of Elk River in NE¼ sec. 33, T. 33N., R. 26W. The original vegetation has almost disappeared, but a few scattered scrub tamaracks remain. A large part of the bog is covered with grasses and patches of bulrushes and low swamp-willows. The peat is underlain by sandy clay. The area consists of only about 40 acres. The average thickness of the peat is about 8 feet, and the maximum thickness, as indicated by test holes, is 11 feet. Holes were located along an east-west line across the bog approximately through the center. Analysis 231 (page 80) represents this bog.

SIBLEY COUNTY

No peat deposits of importance were found in Sibley County. There are small marshes and meadows covered with a few inches of peaty muck, but no peat suitable for the manufacture of fuel was seen.

STEARNS COUNTY

There were originally 40,000 acres of wet, swampy, or overflowed land in Stearns County. This swamp area has been reduced about one half since clearing, drainage, and improvement of waterways began. The present estimate of 20,000 acres of wet land in Stearns County includes much that could be reclaimed at a comparatively small cost. Only a fraction of this wet land is covered by fuel peat.

There are no large peat deposits in Stearns County, but there are many small peat bogs and marshes in which the peat varies from a few inches to 10 feet in thickness. Most of the peat is shallow (less than 5 feet), and in those bogs where the peat attains a depth of 8 or 10 feet, the area covered by peat of that thickness is very small, and usually restricted to an acre or less in the center of the bog. There are 2 types of peat deposits in the county: open marshes and small tamarack swamps. The former predominate. A few of the peat bogs are underlain by marl. Some of the peat is of good quality for fuel, and a few deposits contain sufficient material to make it possible to utilize the bogs for machine peat, where they are located conveniently to railroads. Some typical bogs in the county are described below.

BROOTEN

Locality 129.—Marsh about half way between Brooten and Belgrade, along the Soo railroad. The marsh covers parts of secs. 9, 10, and 11, T. 123N., R. 35W. This sample was taken from the east half of sec. 9. The vegetation on the bog consists chiefly of grasses, sedges, moss, swamp-willows, and a few small poplars. The peat is underlain by sand. The deposit has been built up on a flat, undrained surface. The marsh contains an area of about 640 acres, and the average thickness of the peat is approximately 5½ feet. The maximum thickness, as indicated by test holes is 7 feet. The peat is composed chiefly of sedge and grass remains, with a little moss near the surface. It is brown, firm, fibrous material, grading into black muck at the bottom of the deposit. Test holes were located along an east-west line from the quarter corner on the east side of sec. 9 to the center of the section. Another line of test holes was put down along the railroad from the center of sec. 9 to a point where the railroad crosses the drainage ditch. A third line of holes was put down along this drainage ditch for a distance of 1,000 feet south of the track. Analysis 232 (page 80) represents the peat from this marsh. The deposit contains good fuel peat, and is well situated for development. No further drainage is necessary in this part of the bog, and the surface is firm and level.

ST. CLOUD

Locality 242.—Peat marsh about 5 miles southwest of St. Cloud, 3/4 mile east of the Great Northern railroad, S1/2 sec. 25, T. 124N., R. 29W. The bog is being used as a wild hay meadow. The vegetation consists chiefly of grasses and sedges, but in the center of the area, where the surface quakes, there is an area of 20 acres covered with a heavy growth of reed-grass. The marsh is a marl-filled lake upon which successive accumulations of vegetation have built up a peat deposit above the old lake level.

The area of the marsh is about 160 acres. The peat is only about 2 1/2 feet thick. Below this depth, marl peat occurs which grades downward into marl. The upper layer of peat, 1 foot thick, is brown and fibrous. Below this occurs 1 to 2 feet of firm, decomposed, tough stratified peat, which is underlain by marly material.

The location of the test holes is as follows:

Hole 1—About 1,500 feet southwest of center of section 25; thickness 2 feet.
Hole 2—500 feet southwest of No. 1; thickness 14 feet. Only 3 feet of pure peat. The remainder is marly.
Hole 3—500 feet southwest of No. 2; thickness 7 feet. Only 2 feet of pure peat.

Analysis 233 (page 80) represents this bog.

STEELE COUNTY

There are numerous small areas of peat in Steele County with three or four bogs of workable size. The most important deposits lie in Deerfield Township (T. 108N., R. 21W.), in the northwest corner of the county, around Pelican and Rice lakes, and in Summit Township (105N., R. 20W.) in the south central part of the county. Another good deposit lies just north of the railroad station at the town of Ellendale.

The Deerfield peaty areas extend for a considerable distance back from the shore lines of the lakes, but the workable peat underlies the lake areas. These lakes have recently been drained by large ditches constructed by the county, so the areas shown as water on the map are, in reality, now only marshy tracts upon which standing water accumulates in the wet season of the year, to a depth of from four to twelve inches. These ditches have thus exposed the beds of the lakes, and have rendered available the peat which has accumulated there. All of the peat in the county occurs in open sedge-grass marshes. Samples were taken from the Pelican and Swan Lake deposits, the deposits in Summit Township, and the Ellendale bog. The detailed descriptions of the localities follow.

MERIDEN

Locality 86.—Marsh 3½ miles north of Meriden, on the Chicago and Northwestern railroad. The marsh is covered with grasses, sedges, lake bulrushes, cattails, and water plantain. The peat is underlain by pebbly clay till. The deposit was formed in a shallow lake which occupied a depression in a glacial till plain.

The marsh contains an area of about 480 acres, over which the average depth of the peat is about 2½ feet, with a maximum depth indicated by test holes, of 4 feet. The peat is dark brown to black, spongy near the top and decomposed near the bottom. The upper layers are made up chiefly of sedge and grass remains with some cattails. The lower portion of the deposit shows remains of aquatic plants, in addition to the sedges and grasses. Many shells were seen scattered through the peat. Samples were gathered from the sides of the drainage ditch which was constructed to drain the lake in the middle of this bog. Analysis 234 (page 81) represents this peat. The deposit is too shallow and the peat is too silty for fuel. Much of the land can probably be reclaimed for agriculture.

Locality 87.—Marsh 3¼ miles north of Meriden in the partly drained bottom of Swan Lake; NW¼ sec. 34, T. 108N., R. 21W. Lake bulrushes are dominant on this marsh. Cattails are prominent, while sedges and grasses form a zone around the rim of the bog. The peat is underlain by pebbly, glacial till, and the deposit represents a partly filled lake which was recently drained. The area comprises about 160 acres. The average thickness of the peat is 5 feet and the maximum thickness 6 feet, as indicated by test holes. The peat is soft, plastic, thoroughly decomposed, black in color, and contains much silt, especially in the lower portion of the deposit. It is made up of the remains of aquatic plants. Many shells are scattered through the deposit.

Samples were collected along a drainage ditch from the wagon road to the center of the bog.

Analysis 235 (page 81) represents this peat. This lake was only recently drained. The drainage is not complete and difficulty was experienced due to the fact that the peat was so soft and fluid that it flowed into the ditch from the sides as fast as the ditch was excavated. A large part of the ditch was completely filled with peat at the time the locality was visited. The ash content of the peat is so high that it could not be used for peat fuel. With complete drainage it is probable that much of the area can be reclaimed for agriculture.

ELLENDALE

Locality 91.—Marsh about 5 miles east of Ellendale and 18 miles south of Owatonna, on the Chicago, Rock Island, and Pacific railroad;

secs. 22 and 23, T. 105N., R. 20W. Much of the thick peat is on the farm owned by Mr. H. E. Leach of Owatonna, Minnesota. Sedges, grasses, and a thin covering of moss make up the vegetation on this marsh. The peat is underlain by 3 to 8 feet of impure peaty marl, containing numerous snail shells. The deposit presents clear evidence of having accumulated beneath a shallow lake, which became completely filled with marl and peat. The peat has continued to form on the surface, which is now built up several feet above the original level of the old lake. The marl is underlain by fine-grained, clayey sand.

The marsh contains an area of about 480 acres. The average thickness of the peat as indicated by test holes, is approximately 6½ feet, with a maximum thickness of 9 feet. This does not include the marl at the bottom of the bog. The peat is dark brown to black, fine grained, plastic, and well decomposed below a depth of 3 feet. It turns black upon exposure to the air. The peat in the upper layers is made up of sedge and grass remains. The lower portion of the deposit shows remains of pondweeds and other aquatic plants. Test holes were located along a line from the south corner of secs. 22 and 23, north to Straight River; thence west to the center of sec. 22; thence south to the quarter corner of sec. 22. Analysis 236 (page 81) represents this bog.

The deposit is "spotty" or irregular in depth and quality. The peat along Straight River, for 50 yards on both sides, is silty. The river has meandered and has rendered the peat impure, by washing in mud and clay. The marl, which occurs beneath the peat, was tested and found to be too impure to be of use for cement, or for commercial fertilizer, although it could be used to advantage locally for neutralizing sour soils. The thick peat covering is a feature which will probably prohibit the profitable use of the marl.

Locality 92.—Marsh 6 miles east of Ellendale. This bog connects with that described under Locality 91, by a narrow marsh water course. The vegetation here consists chiefly of sedges and grasses, with a little moss at the grass roots. The peat is underlain by blue clay which could be used for the manufacture of brick. The peat deposit represents a filled lake or pond, around which the peat has accumulated out from the old shore line, and thus increased the area of the bog.

About 320 acres are included in this marsh, and the average depth of the peat is 4 to 5 feet. A maximum depth of 10 feet was noted. The peat is dark brown to black, fine-grained, plastic, and well decomposed. It is made up chiefly of sedge and grass remains, and contains many snail shells near the bottom of the deposit. The upper 12 to 18 inches is fibrous sedge-peat. Samples were taken every 2 feet from the top to the bottom of the peat from two holes located near the center of the bog. Analysis 237 (page 81) represents this bog.

Locality 93.—Marsh ⅛ mile north of Ellendale station on the west side of the Chicago, Rock Island, and Pacific railroad tracks. Sedges and grasses are the dominant plants on this marsh. The peat is underlain by 6 inches of black muck, which is underlain by brown clay. No shells or marl occur, and the absence of aquatic plants in the peat indicates a built-up deposit. The area of the marsh is about 45 acres. The average depth of the peat is approximately 7 feet, and the maximum depth is 9 feet. The peat is dark brown to black, plastic, and well decomposed. It is made up mostly of sedge and grass remains. The peat was collected from top to bottom of the deposit from each of 8 holes located along a line across the bog parallel to the drainage ditch—100 feet north of the ditch. A composite sample was obtained from these holes. Analysis 238 (page 81) represents this sample. This bog is located exceptionally well for the development of a peat fuel plant. The peat is of good quality and has a uniform texture from top to bottom. The bog could be easily and cheaply drained. Upon the basis of 200 tons of air-dry machine peat per acre per foot in depth, this bog contains 63,000 tons of air-dry machine peat fuel. The descriptions given above include the largest peat deposits in Steele County. There are, however, in addition to these, numerous small areas of wet peaty land which could be used for agriculture if properly drained and plowed deep enough to mix the subsoil with the peat.

Another deposit of considerable area lies in Merton Township in the northeast corner of the county. The peat is shallow and lies in the south half of secs. 23 and 24, and extends southward so as to include a strip along the north part of secs. 25 and 26. This bog covers an area of about 400 acres but was not sampled, since it is too far from the railroad at present to be available. The remaining marshy land in the county is widely distributed. Many small marshes contain only a few inches of peat and some contain none at all.

STEVENS COUNTY

There are no peat deposits in Stevens County of sufficient size or depth to be valuable for fuel.

SWIFT COUNTY

Swift County contains no peat of commercial value as a source of fuel.

TODD COUNTY

The northern part of Todd County contains many comparatively small muskeg swamps, most of which have been burned and the timber (tamarack and spruce) destroyed. The southern half of the county contains relatively few bogs, and these are mostly of the meadow or marsh type, and contain no trees. According to the State Drainage Commission,[90] Todd County originally contained 45,000 acres of swamp or overflowed land. Only about half of this area is peat covered, and of those bogs which do contain peat, only a relatively few are of possible commercial value as a source of machine peat fuel. Much of the land now classed as swamp land will eventually be made available for agricultural purposes, when it is cleared and thoroughly drained. The peat deposits vary in depth from a few inches to 12 feet. The bogs described below are typical of the two types in the county.

LINCOLN

Locality 237.—Burned tamarack swamp, about 2 miles northwest of Lincoln along the Northern Pacific railroad. Large sedges, grasses, cattails, swamp birch, swamp laurel, buck bean, moss, swamp ferns, and dead tamarack were noted on this bog. The area has been burned many years ago and the surface is still covered in places with fallen trees, logs, and stumps. The deposit represents a peat-filled lake. The main part of the bog comprises an area of about 1 square mile, but there are several long narrow arms extending out from the central area not included in this estimate. The average thickness of the fuel peat as indicated by test holes is about 7 feet. The maximum thickness is 13 feet, including 5 to 6 feet of green pond peat near the bottom, which is not suitable for fuel. The peat is brown and fibrous in the upper 9 feet of the deposit, below which it changes to soft, structureless, decomposed greenish pond peat. The upper layers are made up chiefly of sedge remains, while aquatic plants comprise the material in the lower layers. Test holes were put down along the line running south from a railroad bridge which is located at the edge of the bog. The locations of the test holes are as follows:

Hole 1—1,000 feet south of bridge; thickness 7 feet.
Hole 2—1,000 feet south of No. 1; thickness 11 feet.
Hole 3—1,000 feet south of No. 2; thickness 13 feet.
Hole 4—1,000 feet south of No. 3; thickness 9 feet.
Hole 5—1,000 feet south of No. 4; thickness 11 feet.

Analysis 239 (page 81) represents this deposit.

Locality 238.—Bog containing an area of about 100 acres, 3½ miles northwest of Lincoln along the Northern Pacific railroad. The thickness of the peat here is 1 to 2 feet. It is black, gritty material and approaches the composition of muck. It has no value and no samples were taken.

PHILBROOK

Locality 239.—Marsh about 1½ miles southeast of Philbrook along the Northern Pacific railroad. The vegetation consists chiefly of sedges,

[90] George A. Ralph, *op. cit.*

grasses, reed-grass, goldenrod, weeds, and a fringe of tamarack and spruce trees at the east edge of the bog. The area has been burned, and charred stumps and roots indicate that originally most of the area was covered with tamarack and spruce. The marsh lies in a peat-filled depression among rather high, steep, morainic hills.

The area of the marsh is about 900 acres. The average depth of the peat, as indicated by test holes, is about 3½ feet, with a maximum depth of 5 feet. The peat is decomposed, plastic, structureless, brown of color, and gives off an odor of hydrogen-sulphide gas. Some sand is mixed with the peat. It is made up chiefly of sedge and cattail remains, with a little woody fibre and some roots.

Test holes were located as follows:

Hole 1—About ¼ mile southeast of mile post 133 along railroad; thickness 3 feet.
Hole 2—¼ mile southeast of No. 1 along railroad; thickness 4 feet.
Hole 3—¼ mile southeast of No. 2 along railroad; thickness 5 feet.
Hole 4—At mile post 132 along railroad; thickness 3 feet.

Analysis 240 (page 81) represents this bog. The area is flooded after heavy rains, and a large amount of sand has been washed in and mixed through the peat, which accounts for its high ash content.

BIRCH LAKE CITY

Locality 240.—Meadow about 2 miles north of Birch Lake City, and 2 miles west of Grey Eagle, in secs. 10, 11, and 15, T. 127N., R. 33W. The marsh is being used as a hay meadow. Grasses and sedges constitute the only vegetation except at the shore of a small lake which occurs at the east edge of the bog, where sedges and moss are the only plants growing. The bog near the lake is of the quaking type, and evidently consists of a floating sedge mat. The deposit represents a lake which has become filled with marl and peat. The peat is underlain by marl, and the marl is underlain by sand. The area of the marsh consists of about 200 acres. The average thickness of the peat is from 10 to 12 feet, but all except the upper 2 feet is marly and contains numerous snail shells. Test holes were located along a road across the bog, extending southwest and northeast from the southwest corner of sec. 11 as follows:

Hole 1—200 feet north of margin of bog; thickness 2 feet brown peat. 10 feet marl.
Hole 2—200 feet northeast of No. 1; thickness 2 feet brown peat. 10 feet marl.

Analysis 241 (page 81) represents this peat.

Locality 241.—Marsh about 3 miles north of Birch Lake City, and 1½ miles west of Grey Eagle on Northern Pacific railroad. The greater part of the marsh is being used for a hay meadow. There are a few small tamarack trees at the west edge, and some reed-grass occurs around a small lake at the east edge. The marsh was originally a tamarack swamp.

The area comprises about 200 acres, and the average thickness of the peat as indicated by test holes is approximately 7 feet. The peat is brown, fibrous, and of uniform texture. It is made up mostly of the remains of sedges, reeds, cattails, and twigs and leaves of heath shrubs. Test holes were located along an east-west line, ¼ mile south of the north boundary of sec. 2, turning southeast at the east edge of sec. 2, and extending from this point southeast to the shore of a small lake at the east edge of the bog. The locations of the holes are as follows:

Hole 1—¼ mile east of west edge of sec. 2; thickness 9 feet. Small tamaracks.
Hole 2—¼ mile east of No. 1 at road; thickness 4 feet.
Hole 3—¼ mile east of No. 2; thickness 7 feet. Hay meadow.
Hole 4—¼ mile east of No. 3, on east line of sec. 2; thickness 5 feet. Hay meadow.
Hole 5—¼ mile southeast of No. 4; thickness 6 feet. Quaking bog.
Hole 6—¼ mile southeast of No. 5; thickness 7 feet. Quaking bog.
Hole 7—¼ mile southeast of No. 6 at shore of lake; thickness 8 feet. Quaking bog.

Analysis 242 (page 81) represents the peat in this marsh. Drainage ditches were being excavated across this marsh at the time of investigation. The deposit contains good fuel peat.

TRAVERSE COUNTY

There is no peat in Traverse County.

WABASHA COUNTY

There are no peat deposits in Wabasha County of sufficient size to merit discussion.

WADENA COUNTY

In the northern and western portions of Wadena County there are numerous small tamarack swamps, while in the southern and eastern parts the bogs are mostly open marshes, and are being used for hay meadows. The total area of wet or swamp land in the county has been estimated to be 80,000 acres. Only a fraction of this area is covered with peat deposits of possible fuel value. Much of the swamp land is covered with black muck containing from 50 to 75 per cent of mineral soil. Most of the tamarack swamps have been burned at some stage in their history, and on many such areas only dead trees, or stumps, remain to indicate the character of the original vegetation. The deposits described below are typical of the region in which they occur, and contain no fuel peat in workable quantities. The only bogs of possible commercial value as sources of peat fuel occur in the northern part of the county.

WADENA

Locality 230.—Hay meadow, 2 miles south of Wadena along the Great Northern railroad. Sedges and grasses are the only plants of importance growing on the meadow. The peat is underlain by sand or sandy glacial till.

The area contains about 640 acres. The average thickness of the peat is 5 feet, but only the upper 2 feet is usable. The top 6 inches is composed of roots of living plants. Below the living vegetation is a thin layer of gray marly peat containing shells. Below the marly layer, 2 feet of dark brown, fibrous stratified peat occurs. This is underlain by 2 to 3 feet of black gritty peat or muck. The peat is made up mostly of the remains of sedges, reed-grass, and grasses. There are many seeds of various plants in the peat. The locations of the test holes are as follows:

Hole 1—200 feet south of north margin, along railroad; thickness 2 feet.
Hole 2—¼ mile south of No. 1 along railroad; thickness 5 feet.
Hole 3—¼ mile south of No. 2, along railroad; thickness 5 feet.
Hole 4—¼ mile south of No. 3; thickness 3 feet.

Analysis 243 (page 81) represents this peat.

Locality 229.—Marsh about 2 miles northeast of Wadena along Great Northern railroad. This marsh is being used as a hay meadow. There are a few scattered clusters of swamp-willows growing along the creek which flows across the marsh. The area comprises about 2 square miles over which the peat has accumulated to a depth of only about 1 foot. It is black gritty peat or muck, and has no value for fuel, consequently no samples were taken for analysis. Much of the area could probably be reclaimed with proper drainage, for agricultural purposes.

WASECA COUNTY

The peat deposits of this county are all of the open sedge and grass-meadow type, and have been formed (1) in shallow lakes which have been completely filled with the peaty remains of plants, or (2) on low undrained land subject to the overflow from lakes and creeks in wet seasons, or (3) in small undrained basins and low places in the glacial drift. The clayey impervious nature of the soil of this region is an important factor in the origin of the peat, for it holds the water at the surface, in the low places, and thus furthers the growth of marsh plants. The vegetation on the bogs and marshes is typical of that throughout the counties of south central Minnesota, and consists mainly of marsh grasses, sedges, bulrushes, cattails, reed-grass, etc. There is no peat moss in the entire county and only rarely do shrubs appear, and then only as isolated plants.

Waseca County contains several large peat deposits of distinct commercial value, and a large number of bogs containing good fuel peat, but of insufficient size to warrant exploitation. The best and largest deposits all lie in the northern part of the county in Blooming Grove, Woodville, Iasco, and Janesville townships. The most important deposit lies just east of Watkins Lake, and embraces parts of secs. 34, 35, and 36; T. 108N., R. 22W.; and secs. 1, 2, and 3, T. 107N., R. 22W. This deposit, as well as two other bogs, one bordering Rice Lake on the west, and the other along the southeast shore of Clear Lake, were tested, and the results are given below, together with detailed descriptions of the bogs.

WASECA

Locality 88.—Marsh extending back from the south shore of Clear Lake, 1 mile east of Waseca. Grasses, sedges, bulrushes, and cattails comprise the vegetation on the surface. The peat is underlain by pebbly clay. The marsh contains an area of about 100 acres. The average thickness of the peat, as indicated by test holes, is approximately 5 feet. The peat is dark brown to black, rather fibrous and of an even texture. It is composed chiefly of sedge and grass remains. Only one test hole was put down. This was located in the center of the bog, and a composite sample was taken from the top to the bottom of the peat. Analysis 244 (page 81) represents this sample.

Locality 89.—Marsh about 4 miles northeast of Waseca and just east of Watkins and Rice Lake. Sedges (*Carex*), with grasses and bulrushes comprise the chief vegetation. The central portion of the marsh is fringed by a wide zone of reed-grass and cattails. The peat is underlain by pebbly, brown clay. The deposit probably represents a filled shallow lake.

The marsh contains an area of about 3 square miles. The average depth of the peat as indicated by test holes is 8 feet. The maximum thickness is 10 feet. The peat is dark brown, clean, and somewhat fibrous, although the fibres are very short. The peat gives a distinct acid test with litmus paper. It is made up mostly of sedge and grass remains, and with numerous flattened bulrush stems and reed-grass. Test holes were located along the large county drainage ditch running north and south through the marsh, about 20 rods east of a line between secs. 35 and 36. The peat is continuously exposed in the sides of the ditch. Samples for analysis were collected from numerous points along the ditch for a distance of ¾ mile from the north edge of the bog, to island near the center.

Analysis 245 (page 81) shows the composition of this peat. This is the largest bog in Waseca County and contains at least two million tons of air-dry machine peat. However, the ash content is too high for good fuel peat, and it is doubtful if this bog could be profitably developed for machine peat fuel.

Locality 90.—Marsh about 2 miles north of Waseca on the west shore of Rice Lake. The vegetation consists chiefly of sedges and grasses, and the peat is underlain by plastic, blue clay, free from pebbles, which might be utilized in the manufacture of brick. The area of the marsh is about 200 acres, and the average depth of the peat is 5 feet. It is dark brown, soft, well decomposed peat, consisting of the remains of sedges and grasses. Test holes were located at 100-foot intervals along a ditch crossing the bog from north to south. Analysis 246 (page 81) represents this peat.

WASHINGTON COUNTY

Washington County contains a large number of lakes in the northern portion, while the southern half of the county contains almost none. In the lake region of the county there are numerous small peat bogs, most of which lie around the lake shores, or in depressions in the moraine, which occur there. The peat bogs are of 2 types; small tamarack swamps, and meadows. Many of the small meadows were originally covered with tamaracks, as shown by stumps and roots found in the peat. A few of the bogs represent small, unimportant, peat-filled lakes. None of the deposits are large, and no good fuel peat was found close to the railroad within the county boundaries. An excellent deposit of fuel peat occurs just west of the Washington County line, in Ramsey County, in sec. 1; T. 30N., R. 22W. For a description of this peat deposit, see the discussion of the Ramsey County peat bogs, page 207 of this report.

WATONWAN COUNTY

There is no peat in Watonwan County of commercial value. The areas of marsh or meadow land are small and most of them are covered with a black muck, in which the per cent of mineral matter is much higher than peat. The three largest marshes in the county contain some peat, but the greatest depth is not more than 20 inches. One of these marshes lies along the Chicago, St. Paul, Minneapolis, and Omaha railroad tracks, 1½ miles northeast of St. James, in sec. 7; T. 106N., R. 31W. This marsh contains about 100 acres, and half of this area contains peat about 20 inches thick. Another peaty area lies 2 miles east of St. James, and extends northwest-southeast through secs. 19, 20, and 28; T. 106N., R. 31W. This land is covered with a few inches of peat. The third marsh of noteworthy size lies 2½ miles south of Madelia, in secs. 2, 3, and 11; T. 106N., R. 30W., and contains about 300 acres. Most of these areas are used for hay meadows or pasture, and some of the land is plowed for crops.

WILKIN COUNTY

There is no peat in Wilkin County.

WINONA COUNTY

There is no peat in Winona County.

WRIGHT COUNTY

There are no large swamps in Wright County, but numerous small meadows or marshes occur, and some of these contain peat. The county is dotted with numerous lakes, and many of the small peat marshes are associated with these lakes. One of the largest of the marshes in the county occurs in secs. 10, 11, 14, and 15, T. 119N., R. 26W., about 2 miles south of Buffalo Lake. The peat in the bogs throughout the county varies in depth from a few inches to 8 or 10 feet, the latter depths being found only in a few places and in small areas. The deposits are almost identical in occurrence, character, and composition with those of Meeker County, and they are of little economic importance in comparison with the great swamp which exists in the northern part of Minnesota.

YELLOW MEDICINE COUNTY

There is no peat in Yellow Medicine County.

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