INVENTORY OF PEAT RESOURCES

AITKIN COUNTY, MINNESOTA

MINNESOTA DEPARTMENT
OF NATURAL RESOURCES

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AITKIN COUNTY
MINNESOTA

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Division of Minerals

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INTRODUCTION

Peatlands are one of Minnesota's many natural resources. Estimates of the area they cover range from 2.4 million hectares (5.9 million acres) to 3.1 million hectares (7.6 million acres), which is about 11 to 16 percent of the state's total area (see fig. 1).

About half of Minnesota's peatlands are state-owned or state-administered land and are presently undeveloped. Recent interest in peatland development by private industry for horticultural and energy use prompted the state to investigate peatland management.

In 1976, the Minnesota State Legislature created the Peat Information Program to study current and potential uses of Minnesota's peatlands and to develop policies concerned with their leasing and development. As a part of this program, the Minnesota Peat Inventory Project (MPIP) was initiated to collect information about the location, quality, and quantity of Minnesota peat to aid in future decisions regarding peatland management.

Funded by the Legislative Commission on Minnesota Resources and the Minnesota Legislature early inventory work began in Lake of the Woods, Koochiching, Aitkin, and St. Louis counties. The first report published was *Inventory of Peat Resources in Southwest St. Louis County, Minnesota*.

In 1979, the U.S. Department of Energy (DOE) and the Gas Research Institute (GRI) awarded the State of Minnesota a grant to determine the location and amount of fuel-grade peat in Minnesota that could potentially be harvested and utilized for energy production in an environmentally acceptable manner. This grant enabled the MPIP to accelerate the existing state-funded survey and to collect additional baseline data. A reconnaissance-level peatland survey of Koochiching County was completed, and *Inventory of Peat Resources, Koochiching County, Minnesota* was published with DOE/GRI funding.

The subject of this report is the MPIP reconnaissance-level peatland survey of Aitkin County, which contains 170,050 ha (420,160 ac) of peatland (see fig. 1). The main objectives of this study were to map the resource and to determine the quality, quantity, and energy potential of peat in the county. The report consists of (1) a text that discusses the resource and the survey and (2) a map of the peat resources in Aitkin County.

The survey was completed by the MPIP staff with the assistance of the Minnesota Geological Survey (MGS). The MGS provided the MPIP with a surficial geology map of the county (Hobbs 1981), an accompanying geologic history, assistance with the field work and field data compilation, and cartographic services.

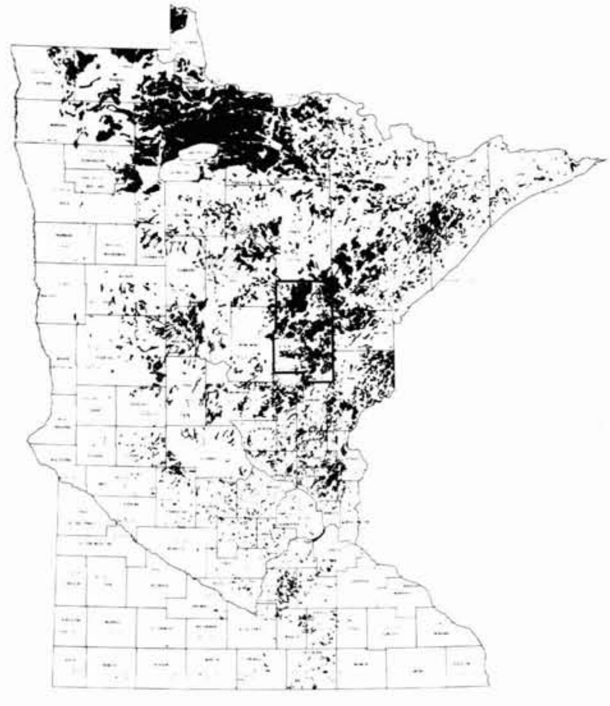

Fig. 1. Distribution of Peat Resources in Minnesota

INTRODUCTION TO PEATLANDS

PEATLAND FORMATION

Requirements for Peat Formation

Peat is an organic soil composed of partially decomposed plant matter. It forms in an unbalanced system where the rate of accumulation of organic materials exceeds the rate of decomposition (humification). Peat formation usually occurs in water-saturated environments, where the wet condition limits the supply of oxygen and, therefore, limits the population of aerobic microorganisms that digest plant remains. These anaerobic conditions greatly reduce the decomposition rates and allow the plant matter to accumulate as peat (Kavanagh and Herlihy 1975).

Peat formation depends on an interaction of climatic and topographic factors, which determine where and to what extent peatlands will occur. Cool, humid climates, where precipitation exceeds evapotranspiration, are generally most favorable to peat accumulation.

Peat deposits are usually found in areas with low, flat, poorly drained topography that allows water-saturated conditions to persist. Peatlands in Minnesota formed primarily in areas that were modified by glacial processes. Glacial landscapes on which peatlands occur include glacial lake plains, ground moraine, end moraine, pitted outwash plains, and outwash plains. Glacial lake plains are large, flat expanses that are usually covered with laminated fine sand, silt, and clay, which restrict drainage. Ground moraine is characterized by poorly sorted deposits and an undulating surface with immature drainage that may slow water movement in some areas. End moraines and pitted outwash plains contain numerous depressions and basins, called kettles, formed when blocks of ice within the glacial drift melted, allowing the overlying sediment to collapse. These kettles often filled with water creating lakes and ponds that are suitable sites for peat accumulation. Outwash plains, generally composed of stratified coarse sand and gravel, are usually characterized by good drainage; however, if a high water table is present they may be suitable sites for peat accumulation.

Peatland Formation Processes

There are two major processes by which peatland formation can occur: lakefill and paludification.

Lakefill is the filling in of lakes and ponds by vegetation (see fig. 2). Following the formation of a lake, deposition of limnic sediment, composed mainly of aquatic plants, begins in the basin. As aquatic sedimentation and infilling from the uplands make the lake shallower around the margins, plants adapted to the wet environment, such as reeds and sedges, become established. These plants die and accumulate as peat around the fringe of the lake forming a surface on which other plants can grow. Gradually the vegetation migrates toward the center of the basin, eventually dies, and accumulates as peat. During the process the peat may initially accumulate as a floating mat around the margin of the lake; however, the peat eventually fills the basin.

Paludification, also called swamping, is the process of peatland expansion caused by a gradual raising of the water table due to peat accumulation (Heinselman 1963) (see fig. 3). It occurs on level or gently sloping terrain and begins with the growth of plants adapted to wet conditions in low areas. The plants die and accumulate as peat under saturated conditions that inhibit decomposition of plant materials. This peat accumulation impedes drainage, raises the water table, and allows the plants to migrate farther from the original area, further impeding drainage and continuing the cycle. Peat expansion from low areas may slowly move upslope and cross drainage divides and may eventually form a continuous blanket of peat over the landscape.

CLASSIFICATION

Peat Classification

Numerous peat classification systems exist, each designed for specific uses. The purpose of the systems vary from classification of the resource for soil scientists and geologists to classification solely for the horticultural peat industry. Most users adopt a combination of classification systems that incorporates criteria that pertain both to the degree of decomposition and to the botanical origin of the soil.

In the United States, systems developed by the Swedish scientist von Post, the USDA Soil Conservation Service (SCS), and the International Peat Society (IPS) are widely used. In the 1920s, von Post developed a system used for assessing the degree of decomposition of undisturbed, undrained peat (Puustjarvi and Robertson 1975). It is a ten-point scale based on physical properties of peat that are observed as a small sample is squeezed in a clenched fist. The amount and the turbidity of the water that is released as the sample is squeezed and the amount of peat that is extruded between the fingers are the classification criteria. The scale ranges from H1 for undecomposed peat to H10 for completely decomposed peat (Table 1).

The Soil Conservation Service developed a system for classifying organic soils that is based on the fiber content of the soil. A fiber is defined as a fragment or piece of plant tissue, excluding live roots, that is large enough to be retained on a 100-mesh sieve (openings 0.15 mm in diameter) and that retains the recognizable cellular structure of the plant from which it came (Soil Survey Staff 1975). This system classifies peat according to a three-grade scale: fibric, peat that contains more than

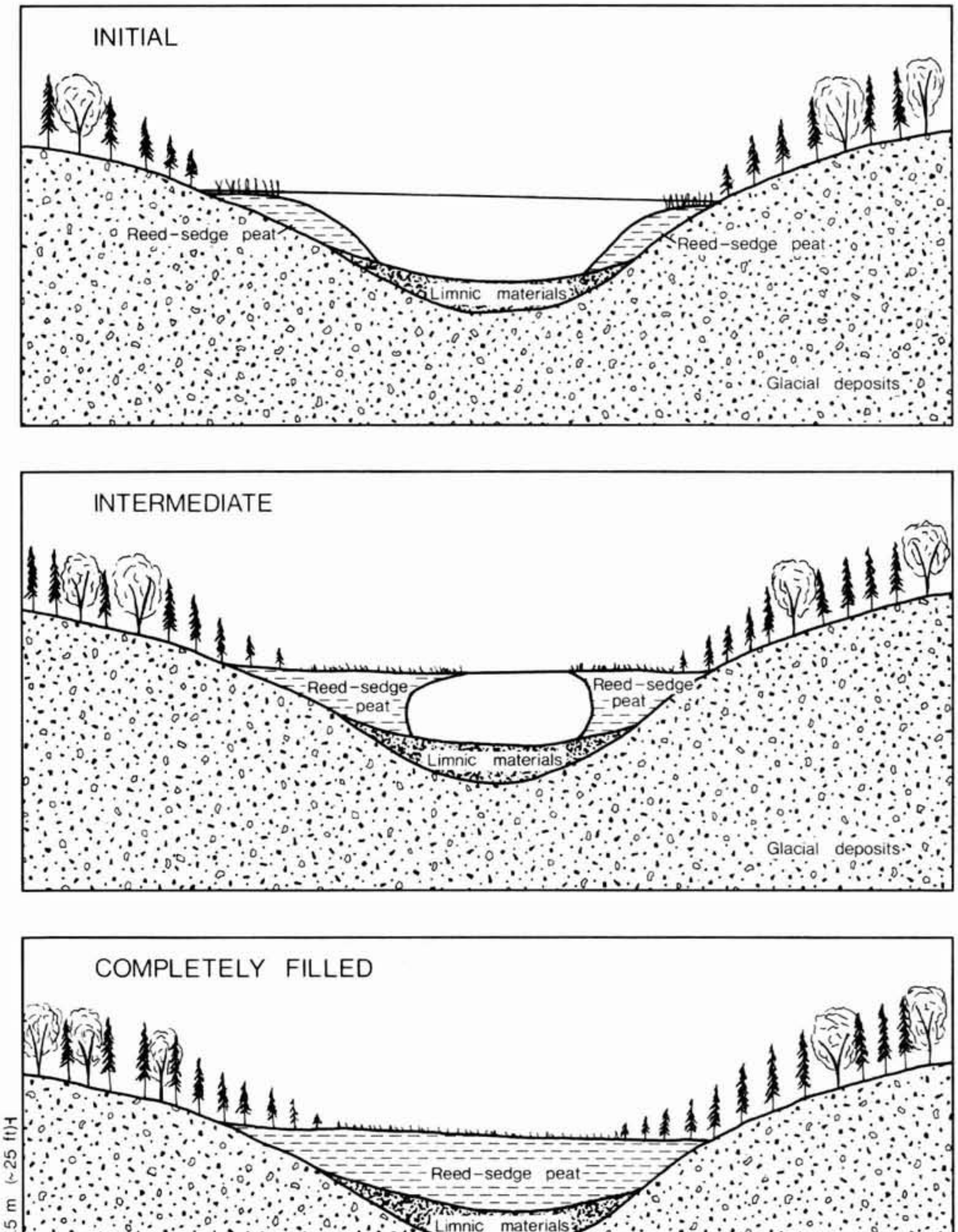

Fig. 2. Lakefill Process of Peatland Formation

66% fiber by volume; hemic, peat that contains from 33% to 66% fiber by volume; and sapric, peat that contains less than 33% fiber by volume. The percentage of fiber is used as a direct measure of the degree of decomposition.

In 1976, the International Peat Society, in an effort to standardize peat classification systems worldwide, published its classification proposal (Table 2). It collapsed the ten-point von Post system into three categories: R1 includes H1-3, R2 includes H4-6, and R3 includes H7-10. The proposal also classifies peat by its botanical origin. The groups include (1) moss peat, composed of plant remains derived from sphagnum and other mosses; (2) herbaceous peat, composed of plant remains derived from sedges, reeds, grasses, and related species; (3) wood peat, containing plant remains from trees and woody shrubs; and (4) mixed groups. Table 3 correlates the von Post, SCS, and IPS classification systems.

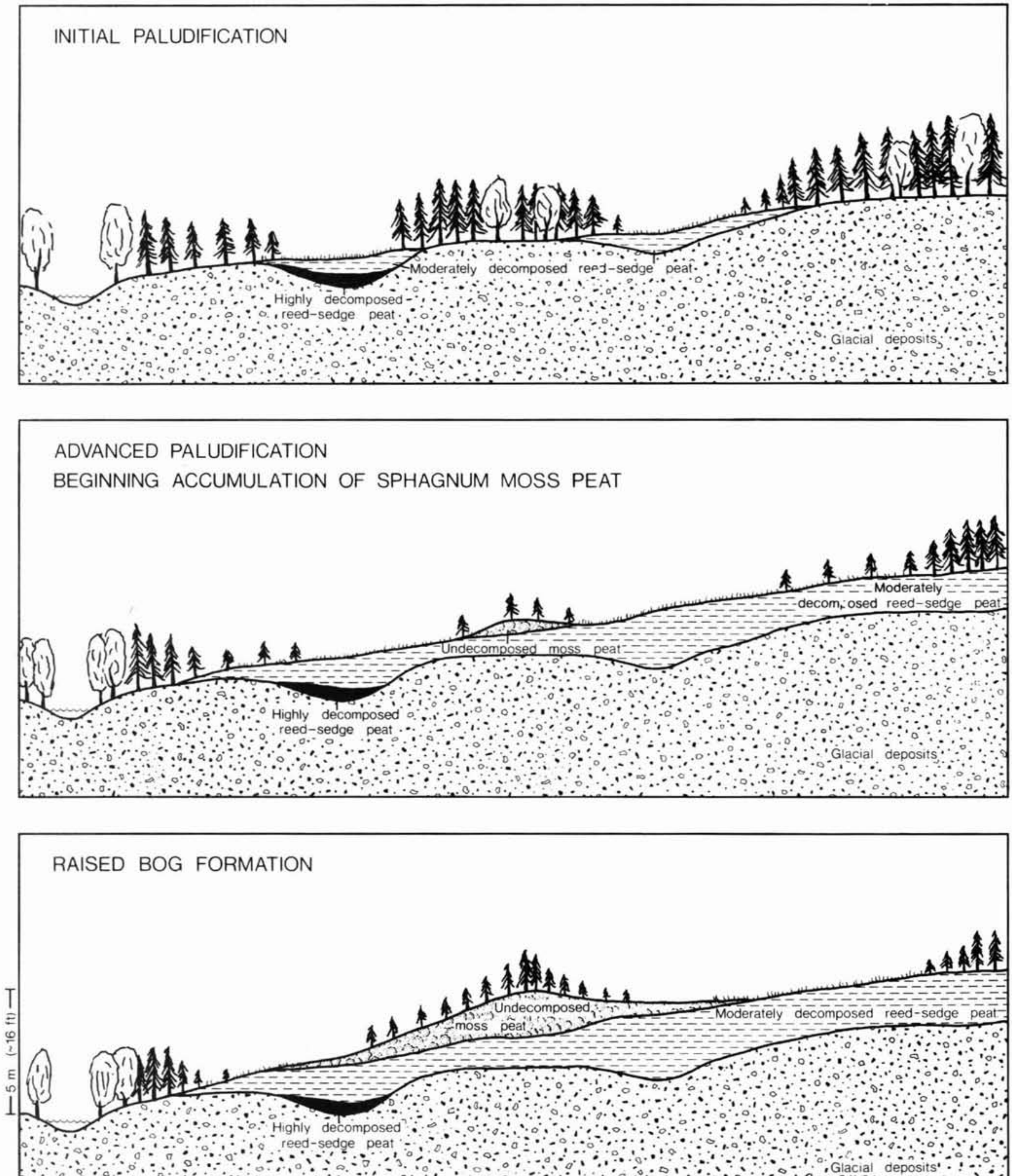

Fig. 3. Paludification Process of Peatland Formation

TABLE 1

MODIFIED VERSION OF THE VON POST SCALE FOR ASSESSING THE DEGREE OF DECOMPOSITION OF FRESH PEAT

Degree of decomposition	*Nature of water expressed on squeezing*	*Proportion of peat extruded between fingers*	*Nature of plant residues*	*Description*
H1	Clear, colourless	None	Unaltered, fibrous, elastic	Undecomposed
H2	Almost clear, yellow-brown	None	Almost unaltered	Almost undecomposed
H3	Slight turbid, brown	None	Most remains easily identifiable	Very slightly decomposed
H4	Turbid, brown	None	Most remains identifiable	Slightly decomposed
H5	Strongly turbid, contains a little peat in suspension	Very little	Bulk of remains difficult to identify	Moderately well decomposed
H6	Muddy, much peat in suspension	One third	Bulk of remains unidentifiable	Well decomposed
H7	Strongly muddy	One half	Relatively few remains identifiable	Strongly decomposed
H8	Thick mud, little free water	Two thirds	Only resistant roots, fibres and bark, etc., identifiable	Very strongly decomposed
H9	No free water	Almost all	Practically no identifiable remains	Almost completely decomposed
H10	No free water	All	Completely amorphous	Completely decomposed

SOURCE: Puustjarvi and Robertson, Peat in Horticulture.

Peatland Classification

Peatlands can be classified by their vegetation, which is a reflection of the water chemistry of the peatland, into fens and bogs. Fens support a wide variety of vegetation, including sedges, cattails, mosses, willow, bog birch, alder, numerous ericaceous shrubs such as swamp laurel and leatherleaf, and tree species such as tamarack, northern white cedar, and black spruce. Fens receive water from precipitation and from ground water that has percolated through mineral soil. The water is usually neutral or slightly acidic and is rich in nutrients.

Bogs support a very limited flora. Sphagnum mosses usually dominate the ground cover, and various densities of ericaceous shrubs are present. Scattered, often stunted, black spruce are common, but dense stands occur locally. Bogs are isolated from the influence of mineral soil and receive water and nutrients solely from precipitation. Bog waters are usually very acidic and nutrient poor.

Raised bogs are a type of bog characterized by a dome-shaped accumulation of fibric sphagnum moss peat usually overlying herbaceous or woody peat (see fig. 3). They begin to form on local watershed divides within peatlands where isolation from mineral-rich water favors sphagnum moss growth (Heinselman 1970; Hobbs 1980). Typical raised bog vegetation patterns can be interpreted from aerial photographs as lines of black spruce radiating outward from a central point or axis. Unforested openings between these lines of spruce are bog drains, where runoff is channelled away from the bog crest (Glaser et al. 1981).

PEAT STRATIGRAPHY

A typical cross section of a Minnesota peatland consists of a thin basal layer of sapric peat, covered by a relatively thick layer of hemic peat, overlain locally by fibric peat (Severson et al. 1980; Olson et al. 1979). The layers within a deposit, which can be differentiated by degree of decomposition and botanical origin, reflect the hydrologic conditions and vegetation cover that existed when the peat was laid down.

Initial peat accumulation is fairly decomposed (sapric) because the aerobic conditions at the surface of a deposit favor a rapid rate of decomposition. As peat continues to accumulate, the resultant rise in the water table produces saturated, anaerobic conditions causing a slower rate of decomposition that is more conducive to

TABLE 2

IPS THREE-GRADE SCALE OF PEAT DECOMPOSITION

Scale grade	*Percent of fibers*	*Structure and look of the peat bulk*	*Presence and look of humus*	*Amount and look of water*
R1 Weakly decomposed peats	>70%	Spongy or fibrous, built of plant residues tied with one another. For separation tearing off the plant residues is required. Easily recognizable plant residues (well preserved). Elastic, compact.	Not visible or occurs in little amounts as a dispersed dark mass, saturating and coloring plant residues.	Great amount of water, which can be easily pressed out and pours as a streamlet. Almost totally pure or slightly brownish. May contain dark humus spots.
R2 Medium decomposed peats	70-40%	Amorphous-fibrous, grass and moss peats contain numerous plant residues of various size; woody peats are more friable due to the presence of wood residues in amorphous humus. When pressed in fingers, transforms into an amorphous, plastic mass.	Distinctly discernible against which plant residues are visible. Humus can be pressed out between fingers of the clenched fist but not more than 1/3 of the taken sample.	Can be pressed out or flows by few drops; usually thick and of dark color/humus. In drained peat slightly colored with humus coagulated in consequence of partly drying.
R3 Strongly decomposed peats	<40%	Lumpy-amorphous, consisting in main part of humus. In lumpy-amorphous peat greater fragments of plant residue/wood, rhizomes, greater rootlets/occur. Friable, disintegrates under pressure. Amorphous peat strongly plastic, with sporadic greater plant residues.	Uniform mass, can be pressed out between fingers of the clenched fist in the amount of a half or the whole of the taken sample.	Cannot be pressed out, instead the humus mass is squeezed.

hemic peat accumulation. Further accumulation of peat can elevate the peat surface above the influence of mineral water. This nutrient-poor environment favors the growth of sphagnum mosses, which modify the environment further by increasing the acidity of the water and by drawing up the water table by capillary action. These conditions further limit the rate of decomposition and fibric peat accumulates.

Variations in this typical cross section can occur. Sapric and fibric peat may be interlayered throughout a profile since short-term climatic changes, such as drought or excessive moisture, affect the water table and, therefore, the degree of decomposition. Man-induced changes, such as ditching, may also affect the rate of decomposition.

USES OF PEAT

The type of peat within a peatland and the extent and depth of a peat deposit are factors that may determine its use. For example, extensive areas of hemic herbaceous peat are necessary for large-scale energy operations because this type of peat has the highest heating value per pound. On the other hand, fibric sphagnum moss peat deposits, which occur in raised bogs, have a high value in the horticultural industry as a soil amendment due to their high water-holding and cation exchange capacities.

A third use of peat is as a chemical raw material for the production of industrial commodities such as peat coke, waxes, and yeasts. The yield of these products is dependent on the botanical origin and degree of decomposition of the peat. For example, sphagnum moss peats yield greater quantities of carbohydrates, used in the production of yeasts, than other peat types (Fuchsman 1978).

In addition to these extractive uses of peat, there are several nonextractive uses of peatlands. These include agriculture, forestry, sewage treatment, preservation, recreation, and the production of energy crops. For a detailed discussion of peat uses, see *Minnesota Peat Program Final Report* (MDNR 1981).

TABLE 3

CORRELATION OF PEAT CLASSIFICATION SYSTEMS

IPS	*von Post*	*SCS*
R1	H1-H3	Fibric
R2	H4-H6	Hemic
R3	H7-H10	Sapric

AITKIN COUNTY PEATLANDS

DEVELOPMENT OF THE PRESENT LANDSCAPE

Glacial

The topography of Aitkin County is mainly the result of glaciation during the most recent glacial period, the Wisconsinan Stage, when glaciers periodically entered Minnesota from the north, northeast, and northwest. The ice advanced in lobes, which protruded off the main ice sheet that covered a large portion of Canada, and followed the preglacial lowlands. As the glaciers advanced, they incorporated rock, previously deposited glacial drift, and soil, depositing this material as they stagnated and retreated.

Three phases of the Wisconsinan Stage affected Aitkin County prior to the Alborn phase (see fig. 4). The Alborn phase (see fig. 5), which reached its maximum about 12,000 years ago, was the last phase of the Wisconsinan Stage to affect Aitkin County. During this phase, the St. Louis sublobe of the Des Moines lobe advanced into the county from the northwest through a topographic low. As the ice lobe flowed through the low, it

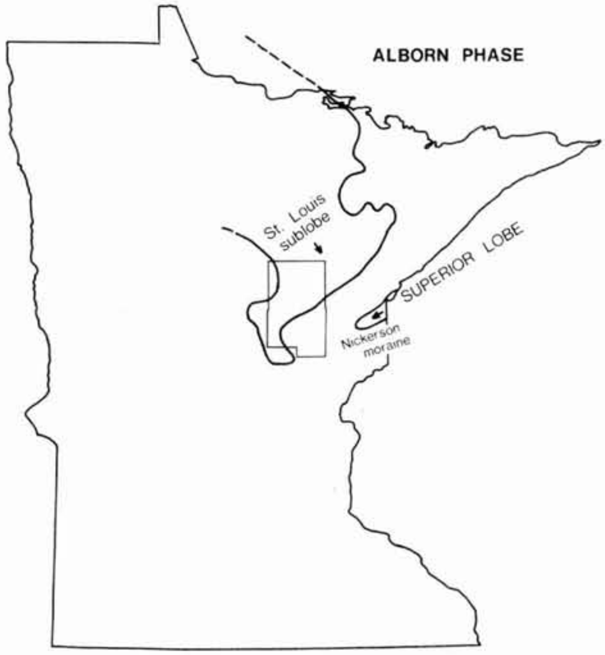

Fig. 5. The Alborn Phase in Relation to Aitkin County (based on Wright 1972*a*)

Fig. 4. Wisconsinan Glacial Phases that Affected Aitkin County Prior to the Alborn Phase (based on Wright 1972*a*)

expanded, covering the lowland roughly delimited by the Mesabi Range and the Mille Lacs-Highland moraine system, which was deposited during a previous phase of the Wisconsinan Stage.

Evidence suggests that the ice temporarily advanced beyond the Mille Lacs moraine to the northern and possibly to the southern shore of Mille Lacs Lake. The ice front then retreated and stabilized, depositing an end moraine on top of the Mille Lacs-Highland moraine (Hobbs 1981). Ice apparently remained at this position for some time, resulting in the formation of an outwash plain between the end moraine and Mille Lacs Lake.

As the Ice Age waned, the St. Louis sublobe stagnated and thinned. The ice in the center of the lobe melted relatively rapidly, while in the end moraine around the perimeter of the lobe a debris cover insulated the ice, preventing rapid melting. Glacial Lakes Aitkin and Upham formed within the lobe, dammed by the ice-cored moraine. The lakes subsequently went through a complicated history of subsiding lake levels, controlled by successively lower outlets formed as the ice front withdrew and the ice within the moraine melted.

Glaciation created an irregular land surface in Aitkin County with many poorly drained or saturated areas. Conditions in these areas eventually became conducive to peat accumulation as the climate changed.

Postglacial

Postglacial landscape changes in Aitkin County have been much less dramatic than the changes during glaciation. The major postglacial processes working to modify the landscape have been soil formation, erosion, and vegetational colonization due to climatic changes.

A general climatic warming trend affected Minnesota from the culmination of the Alborn phase, 12,000 years ago, until about 6,000 years ago when the trend reversed. As the glacial ice retreated from Aitkin County, tundra vegetation established itself on the newly exposed land surface. Continued retreat of the ice and warming of the climate allowed a boreal spruce forest to replace the tundra. The boreal forest was present in Aitkin County until about 10,000 years ago when pine, birch, and alder invaded central Minnesota. Further warming and drier conditions led to the invasion of prairie vegetation about 8,000 years ago. The prairie dominated most of Aitkin County until about 6,000 years ago when a climatic reversal led to cooler, more humid conditions and to the reestablishment of forest communities (Wright and Watts 1969). This climatic change also resulted in conditions favorable to peatland formation. Peat composed of reeds, sedges, and woody shrubs began to accumulate on the fringes around lakes and ponds and on glacial lake plains and other poorly drained areas with low relief. By about 4,000 years ago, climatic conditions were conducive to peat accumulation and the margins of the peatlands spread by the paludification process.

Today, peat blankets a large part of the county (see fig. 6). The lake plains of Glacial Lakes Aitkin and Upham, where the largest contiguous peat deposits in the county occur, and scattered areas of poorly drained ground moraine and outwash plains have been covered with peat formed by the paludification process. Within the Mille Lacs-Highland moraine system there are many small peat deposits, some of which formed in kettles by the lakefill process and others that formed on more level terrain by paludification.

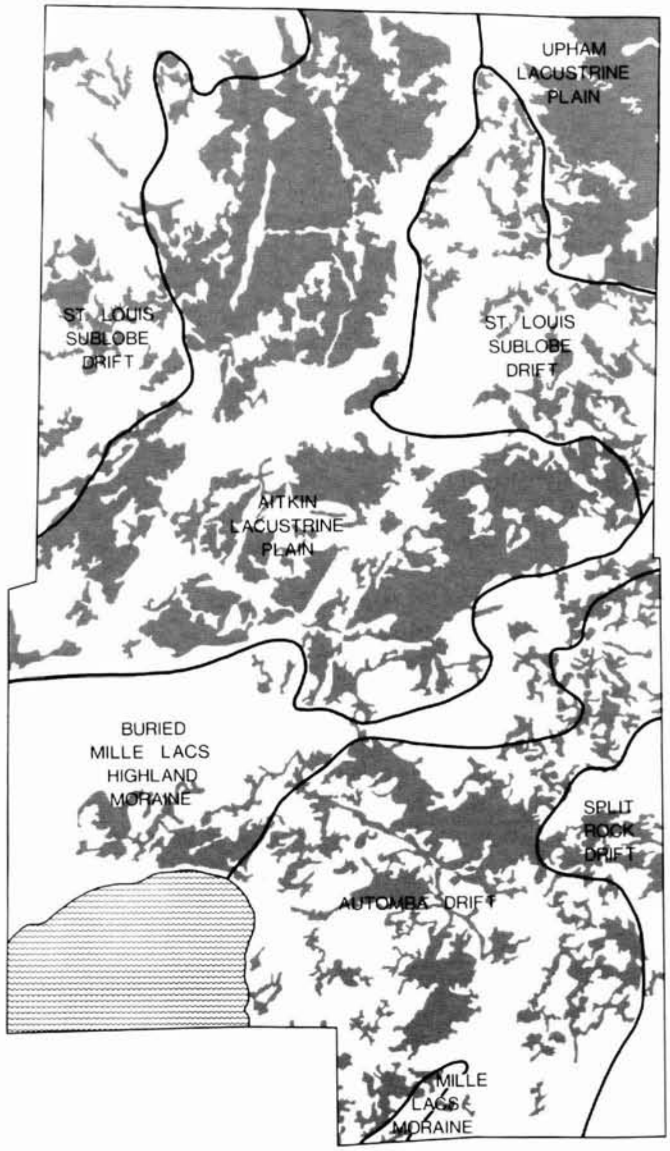

Fig. 6. Peat Distribution in Relation to the Geomorphic Areas in Aitkin County (based on Hobbs 1981)

SURVEY

The MPIP inventoried the Aitkin County peatlands to identify (1) the areal extent, volume, and type of peat found in the county and (2) those peatland areas that meet DOE criteria for fuel-grade peat. Fuel-grade peat (1) has a heating value of 8,000 Btu/lb or more per profile in an oven-dry state, (2) contains less than 25% ash, (3) occurs in deposits that are at least 150 cm (~5 ft) deep, and (4) covers a cumulative area of more than 32 ha (80 ac) per 2.6 sq km (1 sq mi).

This inventory was a reconnaissance-level survey. In this type of survey, the boundaries between mapping units are based on field observations, aerial photograph interpretation between observed sites, and the general appearance of the landscape (Soil Survey Staff 1951). Reconnaissance-level surveys are useful for large-scale resource management and for locating areas that require more detailed mapping.

The inventory data consist of field observations and the results of analysis of peat samples. The map, *Peat Resources, Aitkin County, Minnesota* (in back flap), was compiled from field data, aerial photograph interpretation, and laboratory data.

Field Procedures

The survey began with the interpretation of 1:24,000 United States Geological Survey quadrangle maps and 1:90,000 aerial photographs. The maps and aerial photographs were used to locate peatlands, to determine the relationships between peatlands and the surrounding geomorphic features, and to identify peatland surficial patterns.

The geomorphic features that surround a peatland can indicate the underlying topography, which can provide information on peat depth and the method of peatland formation. The surficial patterns of a peatland, which are variations in vegetation communities, often give clues to the botanical origin and degree of decomposition of the peat.

Observation Sites

Field observation sites were selected, after initial map and air photo interpretation, to provide data on the stratigraphy and thickness of the peatlands. Because of restricted access, sites were limited to those that could be reached by foot when sites were within walking distance from roads, by all-terrain vehicle when sites were near trails, or by helicopter when clearings permitted landing. When an all-terrain vehicle was used, the density of observation sites was increased.

Over 700 sites were visited by the MPIP. At each observation site, the soil profile, natural vegetation, microrelief, and depth to the water table were described. These data appear in a second volume: *Inventory of Peat Resources, Aitkin County, Minnesota, Appendix D; Observation Site Descriptions*. A Davis sampler was used to bring up a small sample at regular intervals in the profile (about every 30 cm) to determine peat thickness, degree of decomposition according to the von Post scale, the botanical origin of each layer within the profile according to the IPS classification, and the texture of the underlying mineral soil.

Sample Sites

The MPIP sampled 188 representative peatland sites for laboratory analysis. Site selection was based on the field observation data in conjunction with information about the peatland topography and landforms, and the relationship between peatland and mineral soil.

The staff used a Macaulay sampler to collect an undisturbed peat sample of known volume at designated intervals in a profile. The samples were placed in plastic bags for later analysis.

At 136 sites, one peat profile was sampled for analysis at the MPIP laboratory in Hibbing. At the remaining sites, two profiles, in close proximity to each other, were sampled at similar intervals. Samples from one profile were analyzed at Hibbing, and samples from the second profile were sent to the DOE Coal Analysis Laboratory in Pittsburgh, Pennsylvania for energy value analysis.

Mapping Procedures

The MPIP field notes and peat information from the Iron Range Resource and Rehabilitation Commission (1965*a*, *b*, *c*, *d*; 1970) were examined and the recorded depths and types of peat were placed into organic soil mapping units. These mapping units differentiate depth, degree of decomposition, and botanical origin of peat. The observation site data were plotted on 1:24,000 scale quadrangle maps. These data, in conjunction with aerial photograph interpretation, were used to draw depth contours at 150 cm (~5 ft) intervals. Next, the areas capped by fibric sphagnum moss peat (raised bogs) were delineated by class intervals showing thicknesses of 20-60, 61-150, and 151-300 cm (~1-2, 2-5, and 5-10 ft). The quadrangles were then reduced to a scale of 1/2 inch: 1 mile, and the peat information was transferred to an overlay, registered to the 1979 highway map of Aitkin County, on which the peat and mineral boundaries were differentiated.

Minor inclusions may occur within each mapping unit due to the effects of generalization during map compilation and production. Two types of generalization that affect the map are (1) the map scale and (2) the number and location of observation and sample sites that served as the control points for drawing the contour lines. The scale of the printed map restricted the size of the mapping unit that could be delineated and labeled to 32 ha (80 ac). The inaccessibility of some peatlands from either ground or air limited the number of observations made.

The mapped information, including both the peat and mineral units at a scale of 1/2 inch: 1 mile, was then manually coded by 40 acre cells and entered into the state's computerized resource information system (Land Management Information Center, Department of Energy, Planning, and Development). The information in this system can be analyzed, combined into selected classes, and output in mapped or tabular form.

Laboratory Analysis

The chemical and physical properties of peat can be used in its classification and to identify use characteristics of a particular type of peat (Walmsley 1977). Peat properties depend largely on the nature and origin of the plant remains composing the peat and the degree of decomposition (Puustjarvi and Robertson 1975).

MPIP Analyses

The MPIP performed ash (mineral) content, moisture content, bulk density, and pH analyses on 872 peat samples from 188 sample sites. These parameters are commonly used to characterize peat. The laboratory methods appear in Appendix A and the data appear in Appendix B.

Ash

Ash is the residue left after a sample is heated to a sufficient temperature to drive off all combustible material. The residue comes from the original peat-forming vegetation as well as from sediment brought into the peatland by runoff from mineral soil and from atmospheric dust. In most peat types, there is a positive correlation between ash content and the degree of decomposition. This is due to the accumulation of mineral matter as a result of mineralization during decomposition (Walmsley 1977).

Moisture Content

Peat has the capacity to absorb and retain large quantities of water. The extent of this capacity depends largely on the degree of decomposition and botanical origin of the peat. Relatively undecomposed peats have a greater water-holding capacity than those that are more decomposed. This capacity is increased in peat composed primarily of sphagnum mosses, because of its cellular structure.

Bulk Density

Bulk density is a measure of the weight of a given volume of soil. The given volume of a sample is usually measured wet because soil volume changes with water content (Walmsley 1977). The bulk density depends upon the organic, mineral, and moisture content of the peat. As the mineral content increases, bulk density increases, and as the moisture content increases, bulk density decreases. Bulk density is found to increase with increasing decomposition and, therefore, can be used as an indirect measure of the degree of decomposition.

pH

Hydrogen ion concentration (pH) is used to measure the acidity or alkalinity of a soil. The pH of peat, which is largely affected by the botanical origin of the peat, can influence the rate of decomposition and therefore the rate of accumulation of organic matter. Peat composed of sphagnum mosses is more acidic than other peat types because of the high cation exchange capacity of the mosses. The acidic condition inhibits microbial activity, thereby slowing the rate of decomposition and increasing the rate of peat accumulation.

DOE Analyses

Energy value analysis was conducted by the DOE laboratory on 254 peat samples from 52 sample sites. The analysis consisted of a determination of the potential heating value, proximate analysis, and ultimate analysis. The data appear in Appendix C.

Heating Value

Heating value is a measure of the energy potential of a peat sample expressed in Britsh thermal units per pound of moisture-free peat (Btu/lb). Heating value is measured in Btu's for small areas but is converted to quads of energy (1 quad = 1×10^{15} Btu) for large areas, such as at a regional or national scale.

Proximate Analysis

Proximate analysis is used to characterize peat in connection with its utilization (Ode 1963). Proximate analysis determines the composition of peat in percentages of moisture, volatile matter, fixed carbon, and ash.

Under natural conditions, the moisture content of peat is approximately 90 percent. Dewatering the peat is the most difficult technical obstacle to utilizing peat as an energy source (U.S. DOE 1979). After a peatland is drained, the peat may still contain from 70-90 percent water.

Volatile matter is the gaseous fraction obtained by heating a peat sample. Volatile matter is an excellent indication of the reactivity of peat to chemical processing (U.S. DOE 1979). The higher the percentage of volatile matter, the more reactive the peat is.

Fixed carbon is the nonvolatile fraction of the combustible material in a peat sample. Fixed carbon is determined by subtracting the percentage of moisture, volatile matter, and ash in the sample from 100 percent. This component provides much of the peat's combustion energy.

The ash content of peat also affects the feasibility of its use in energy conversion. The heating value of peat generally decreases with increasing ash content.

Ultimate Analysis

Ultimate analysis determines the composition of peat in percentages of carbon, hydrogen, nitrogen, sulfur, oxygen, and ash. This information can be used to determine the quantity of potential pollutants and valuable byproducts formed during the chemical processing of peat. For example, the sulfur content of peat is low, therefore, during gasification the formation of sulfur dioxide is minimal. On the other hand, peat is fairly high in nitrogen. During gasification, nitrogen combines with hydrogen to form ammonia, which can be used as a fertilizer.

RESULTS

Peat Types

Aitkin County peatlands contain peat types composed of mosses, reeds, sedges, and some woody fragments. These peat types range from slightly to strongly decomposed. The fibric peat is generally composed of sphagnum mosses. The hemic peat is predominantly herbaceous (reed-sedge) peat or moss peat with some woody peat layers. The origin of the sapric peat is probably herbaceous or woody, but it is difficult to determine in the field because of the high degree of decomposition of the peat.

Peatland Formation

The peatlands in Aitkin County developed by both the lakefill and paludification processes. In some instances, peat accumulation began by the lakefill process, but spread beyond the basin by paludification.

A lakefilled peatland, surveyed in the morainic area of southeastern Aitkin County, is shown in Figure 7. The lakefill process can be identified by the accumulation of limnic sediments at the bottom of the basin. Hemic peat dominates the profile, but some sapric peat and fibric herbaceous peat are found within the profile indicating that the amount of decomposition has varied, as a result of changing drainage characteristics of the peatland.

A peatland in north-central Aitkin County that formed on the plain of Glacial Lake Aitkin is an example of a peatland that developed by the paludification process (see fig. 8). Limnic sediments suggest, however, that peat accumulation began by the lakefill process. Hemic peat dominates the profile, with some accumulation of sapric peat.

Peatland Types

Both peatland types, fens and bogs, are found in Aitkin County. A typical fen that was surveyed by the MPIP is located in the northeastern part of the county (see fig. 9). The peatland formed on the lake plain of Glacial Lake Upham. Near the edge of the peatland, where the peat is shallow, the vegetation consists of speckled alder, bog birch, and an abundance of sedges. Toward the center of the peatland, where the peat deepens, the alder is replaced by scattered tamarack. The peat profile is dominated by hemic peat with an interlayering of fibric herbaceous peat, a layering that is typical of wet fens.

An example of a raised bog, which also formed on the lake plain of Glacial Lake Upham, is located in northeastern Aitkin County (see fig. 10). The vegetation consists of a dense stand of black spruce arranged in the typical raised bog pattern, ericaceous shrubs, and a thick carpet of sphagnum mosses. Surrounding the raised bog, the vegetation is more varied and consists of sphagnum mosses, scattered black spruce and tamarack, and a minor amount of alder and bog birch. The peat profile is characterized by a dome-shaped cap of sphagnum moss peat, underlain by hemic herbaceous peat. Sapric peat and limnic sediments are found at the base of the profile.

The southern limit of raised bog formation in Minnesota occurs in Aitkin County. Therefore, the accumulations of sphagnum moss peat are generally less than in other areas of Minnesota.

Laboratory Data

The results of both the MPIP and the DOE analyses of Aitkin County peat are presented in summary form in Tables 4-11. The standard deviation is the amount of variation of individual sample values about the mean, and the coefficient of variation is a measure of the relative variation of the sample values, expressed as a ratio of the standard deviation to the mean.

Samples with greater than 25% ash are not included in the summary analysis because they do not meet the DOE requirements for fuel-grade peat. The majority of the samples containing greater than 25% ash were taken from just above the mineral soil in a profile, where mineral contamination and mineralization due to decomposition had a probably influence. In a few cases, these samples were taken from the topmost layer of the profile, where the ash concentrations may have been affected by water draining directly off of mineral soil.

MPIP Data

The summary data for ash content, moisture content, bulk density, and pH for 736 samples are presented in Tables 4-7. The sample data, by site and depth, are available in Appendix B.

From the summary data, several trends related to the degree of decomposition are apparent (see fig. 11). These trends follow results found elsewhere (e.g., Walmsley 1977); that is, the ash content, bulk density, and pH increase with increasing decomposition, whereas, moisture content decreases with increasing decomposition.

DOE Data

The summary data for heating value, proximate analyses, and ultimate analyses for 213 samples are presented in Tables 8-11. Moisture content is measured as received; other values are based on moisture-free samples. The DOE data, by site and depth, are presented in Appendix C.

From the summary data, it was found that 202 of the 213 DOE samples met the DOE criteria for fuel-grade peat based on heating value and ash content (i.e., a heating value greater than 8,000 Btu/lb and an ash content less than 25%). Eleven samples contain less than 25% ash, but have a heating value less than 8,000 Btu/lb. The heating values of these samples range from 7,686 Btu/lb to 7,943 Btu/lb. Seven of these samples were taken from just above mineral soil in a profile, while the other four were taken from very near the peatland surface.

Resource Estimation

The map, *Peat Resources, Aitkin County, Minnesota*, was designed to emphasize the peatlands meeting DOE criteria for fuel-grade peat by the use of color and patterns. Five types of areas are depicted on the map: peat greater than 150 cm (~5 ft) deep, peat less than 150 cm deep, peat with a variable depth of 0-300 cm (~0-10 ft), areas with sphagnum moss peat caps, and mineral. Since samples of all three peat types, fibric, hemic, and sapric, generally have heating values greater than 8,000 Btu/lb with an ash content less than 25%, depth and size criteria became the factors for determining fuel-grade peat.

Fuel-grade peatlands, shown in dark orange on the map, are greater than 150 cm deep and cover at least 32 ha (~80 ac). Shallow peatlands, peatlands that are less than 150 cm deep and therefore not meeting the DOE fuel-grade peat criterion for depth, are shown in light

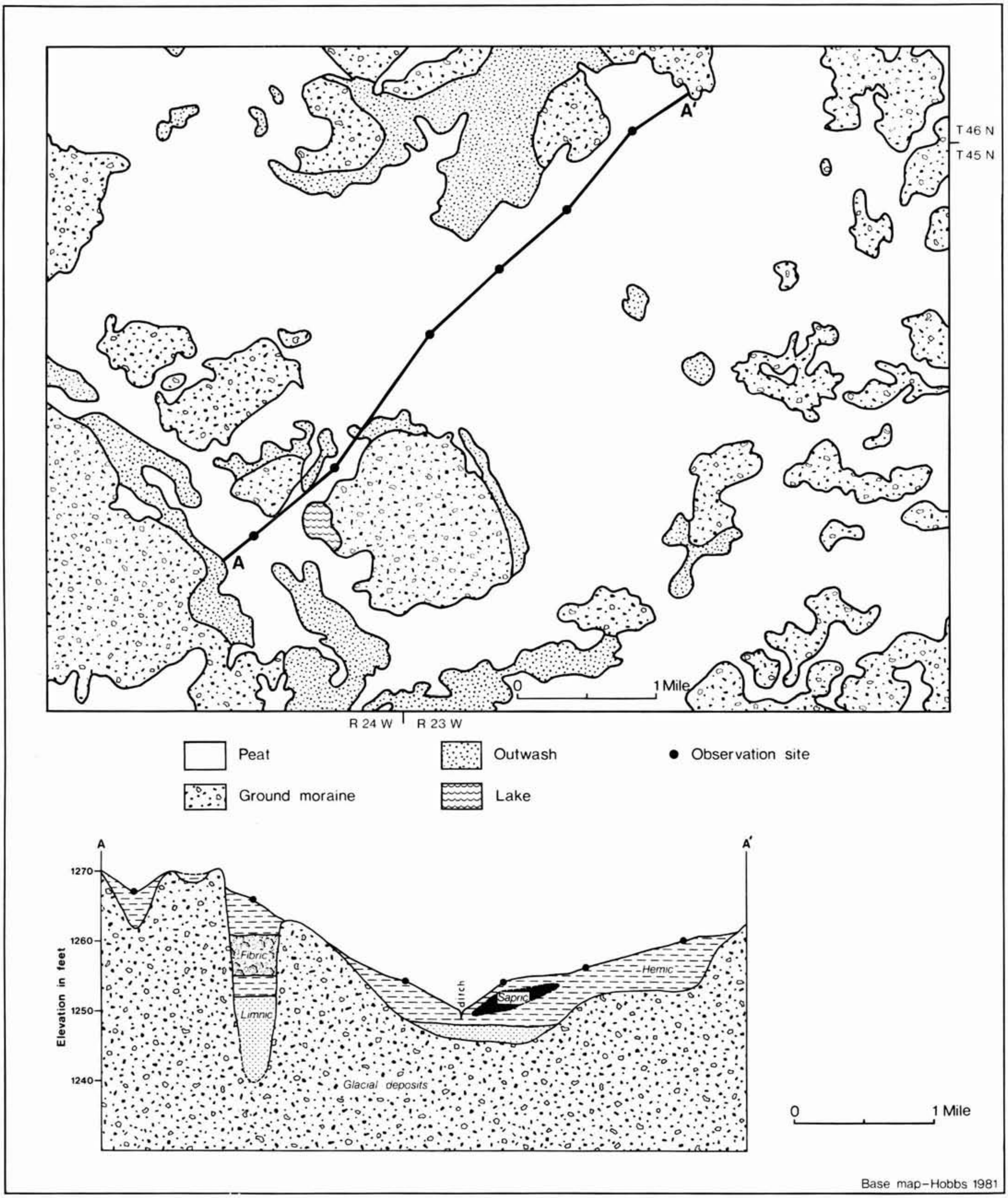

Fig. 7. Peatland in Aitkin County Formed by the Lakefill Process

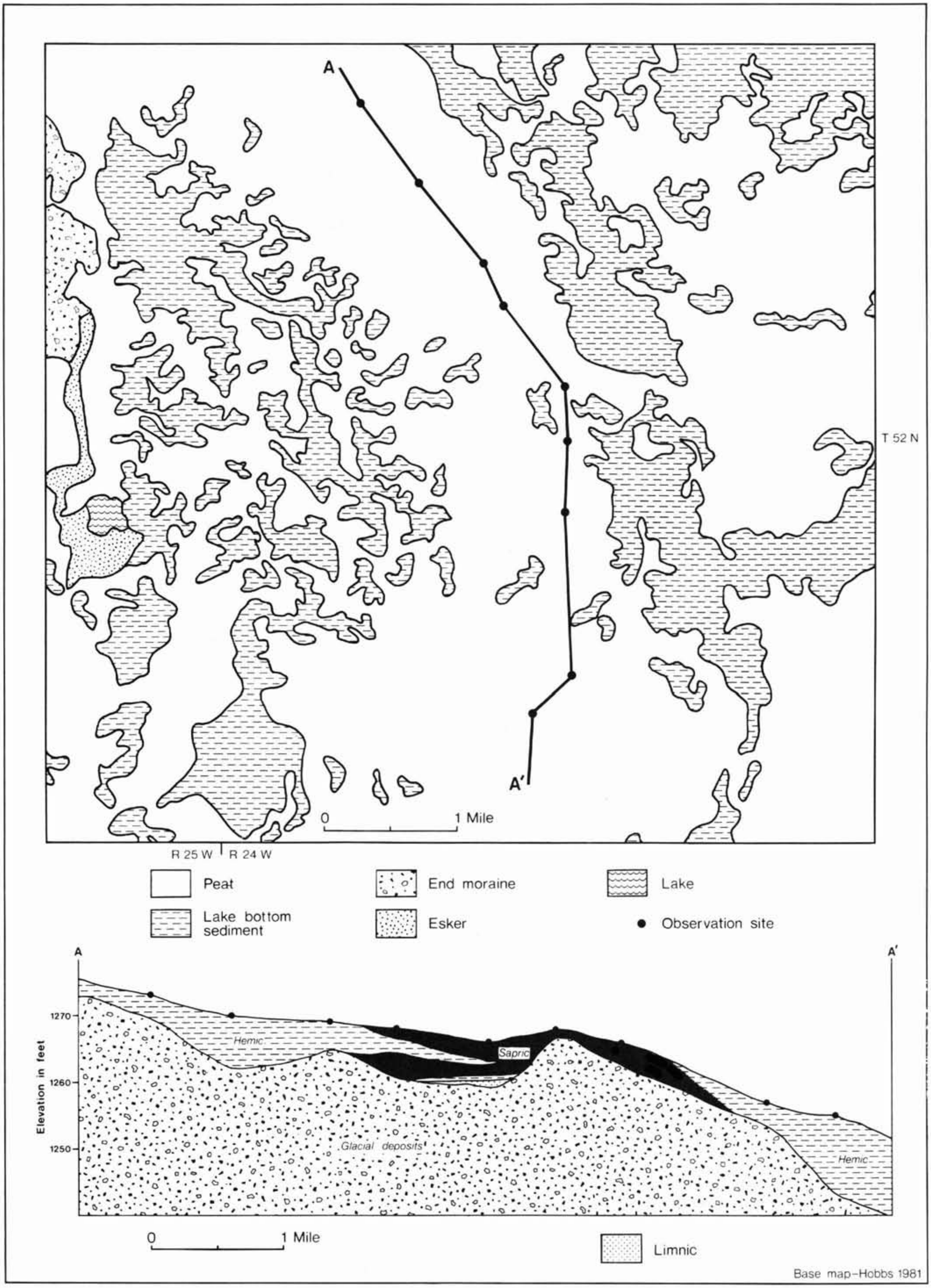

Fig. 8. Peatland in Aitkin County Formed by the Paludification Process

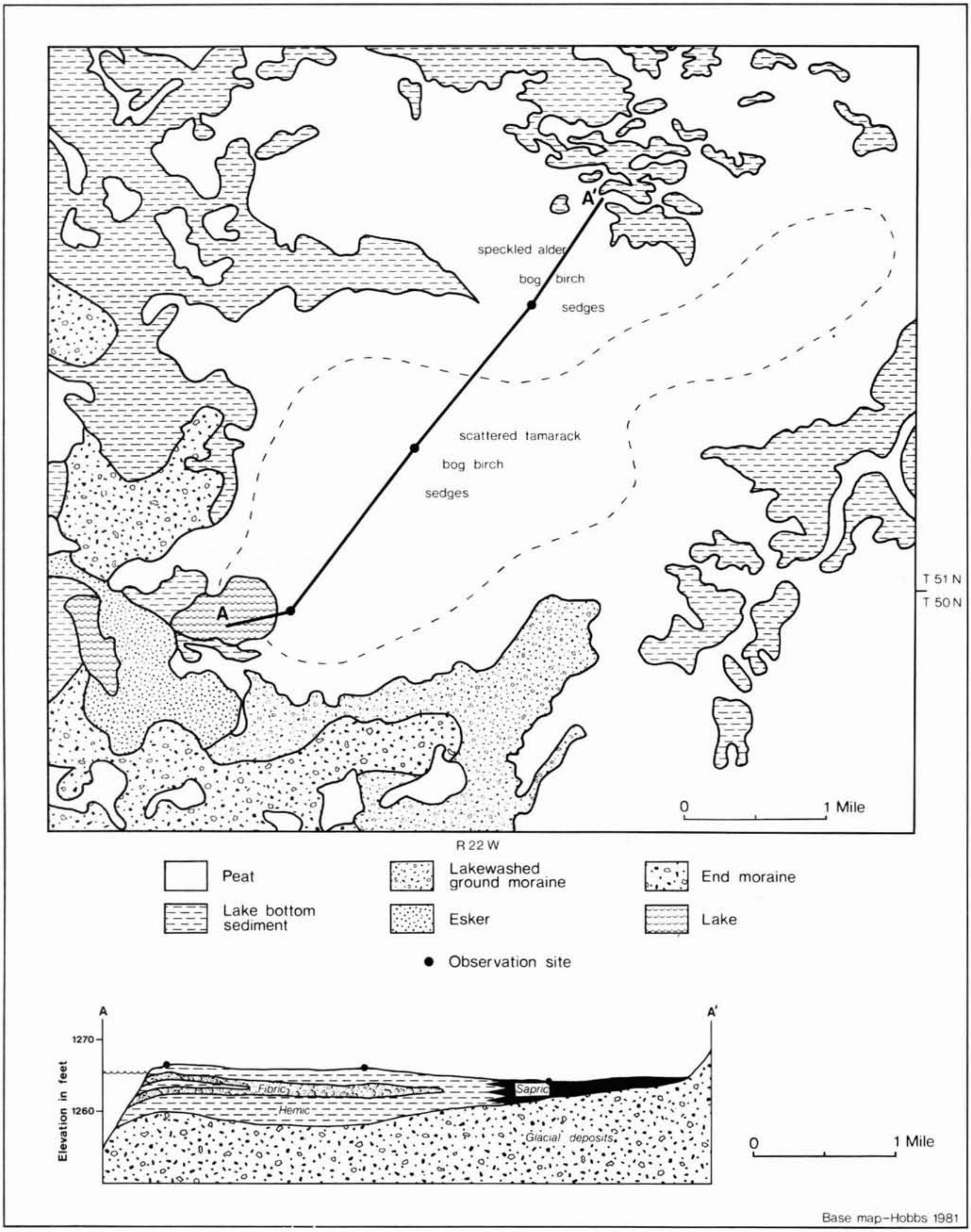

Fig. 9. Fen in Aitkin County

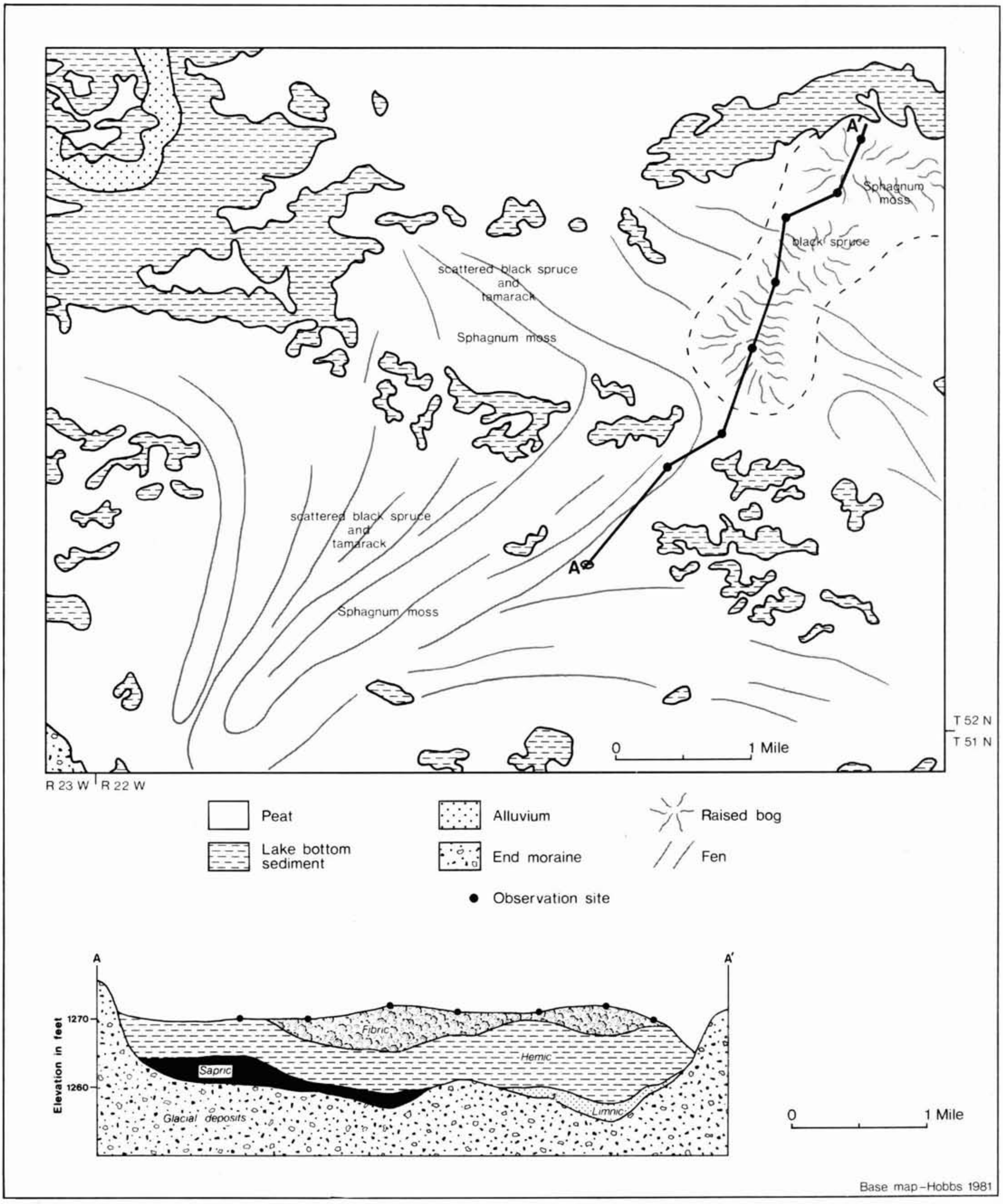

Fig. 10. Raised Bog in Aitkin County

TABLE 4

SUMMARY OF MPIP ANALYSES

	Average	Range	Standard Deviation	Coefficient of Variation
Ash Content (%)	10.9	3.1-24.7	4.63	42.5
Bulk Density (g/cc)	0.13	0.03-0.33	0.40	30.8
Moisture Content (total wt) (%)	87.3	70.8-95.4	3.51	4.0
Moisture Content (dry wt) (%)	752	243-2088	251.66	33.5
pH (H_2O)	5.2	3.2-6.9	0.77	14.8
pH ($CaCl_2$)	4.4	2.4-6.2	0.82	18.6

NOTE: Data from 736 samples containing less than 25% ash.

TABLE 5

MPIP ANALYSIS—FIBRIC SAMPLES

	Average	Range	Standard Deviation	Coefficient of Variation
Ash Content (%)	8.8	3.3-24.7	5.28	60.0
Bulk Density (g/cc)	0.10	0.04-0.18	0.03	30.0
Moisture Content (total wt) (%)	90.3	83.1-95.4	2.80	3.1
Moisture Content (dry wt) (%)	1032	491-2088	377.7	36.6
pH (H_2O)	5.0	3.2-6.9	1.05	21.0
pH ($CaCl_2$)	4.1	2.4-6.1	1.07	26.1

TABLE 6

MPIP ANALYSIS—HEMIC SAMPLES

	Average	Range	Standard Deviation	Coefficient of Variation
Ash Content (%)	10.3	3.1-24.4	4.06	39.4
Bulk Density (g/cc)	0.13	0.03-0.33	0.04	30.8
Moisture Content (total wt) (%)	87.7	70.8-94.0	3.16	3.6
Moisture Content (dry wt) (%)	761	243-1573	218.08	28.7
pH (H_2O)	5.1	3.2-6.5	0.75	14.7
pH ($CaCl_2$)	4.4	2.5-6.0	0.78	17.7

TABLE 7

MPIP ANALYSIS—SAPRIC SAMPLES

	Average	Range	Standard Deviation	Coefficient of Variation
Ash Content (%)	16.3	7.0-24.7	4.39	26.9
Bulk Density (g/cc)	0.18	0.09-0.33	0.03	16.7
Moisture Content (total wt) (%)	82.7	70.8-90.8	2.81	3.4
Moisture Content (dry wt) (%)	495	243-987	106.77	21.6
pH (H_2O)	5.5	4.0-6.6	0.56	10.2
pH ($CaCl_2$)	4.9	3.1-6.2	0.62	12.7

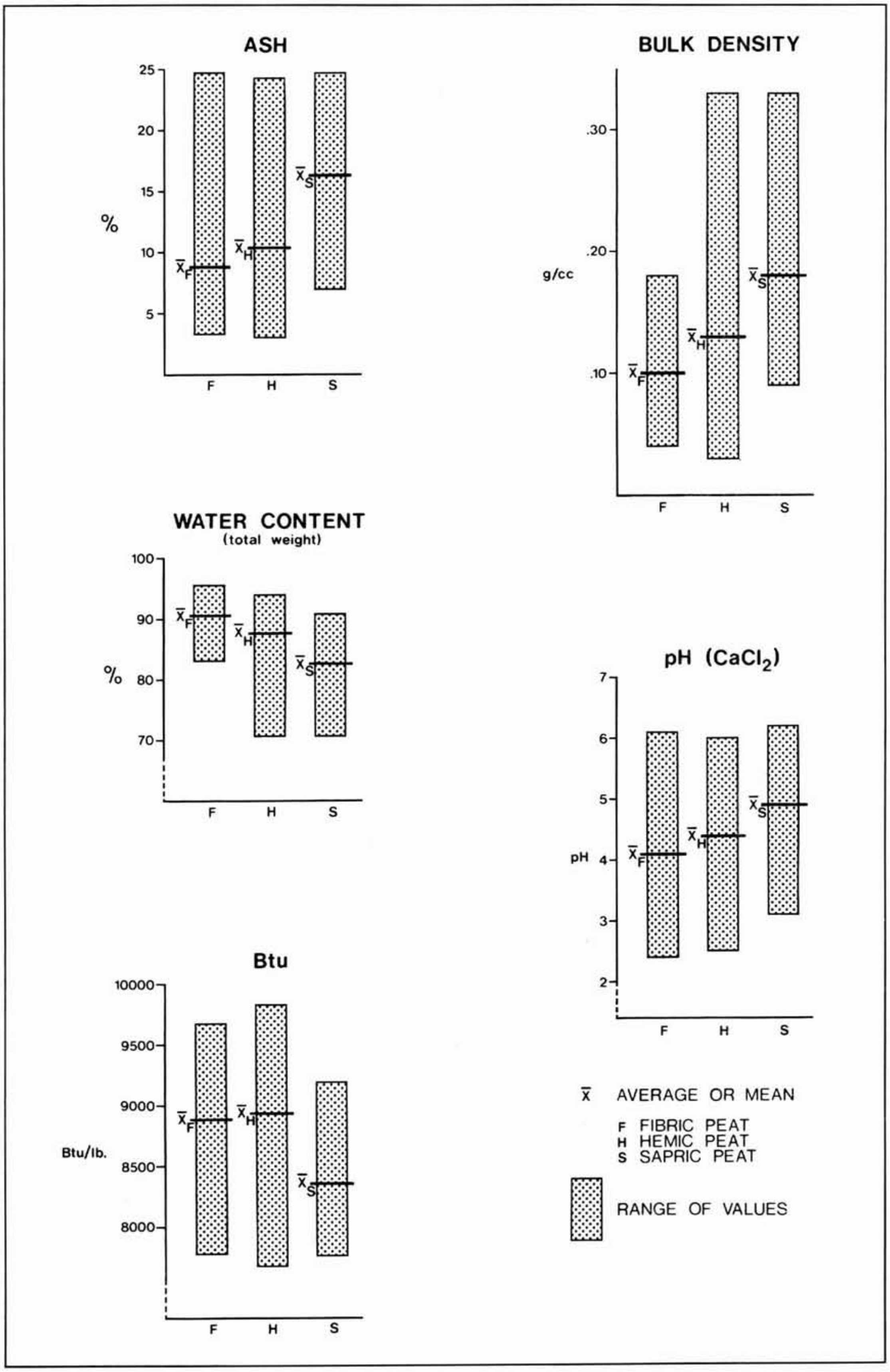

Fig. 11. Degree of Decomposition Versus MPIP Analyses and DOE Heating Value (Btu) Analysis

TABLE 8

SUMMARY OF DOE ANALYSES

	Average	Range	Standard Deviation	Coefficient of Variation
Btu/lb	8874	7686-9839	451.86	5.1
Ash Content (%)	10.6	3.3-24.7	4.74	44.7
Moisture Content (total wt) (%)	88.5	76.1-96.0	3.42	3.9
Volatile Matter (%)	62.9	49.9-74.3	4.76	7.6
Fixed Carbon (%)	26.5	17.3-38.0	2.44	9.2
Hydrogen (%)	5.2	4.2-6.0	0.38	7.3
Carbon (%)	51.8	43.1-55.7	2.44	4.7
Nitrogen (%)	2.5	0.5-4.1	0.62	24.8
Sulfur (%)	0.3	0.1-1.5	0.24	80.0
Oxygen (%)	29.5	22.2-40.6	3.06	10.4
Bulk Density (g/cc)*	0.13	0.05-0.28	0.04	30.8
pH (H_2O)*	5.5	3.8-6.9	0.69	12.5
pH ($CaCl_2$)*	4.6	2.9-6.0	0.78	17.0

NOTE: Data from 213 samples containing less than 25% ash.
* Analysis performed in MPIP laboratory (samples from DOE site, but from a second profile).

TABLE 9

DOE ANALYSIS—FIBRIC SAMPLES

	Average	Range	Standard Deviation	Coefficient of Variation
Btu/lb	8885	7761-9677	378.40	4.3
Ash Content (%)	9.0	3.3-23.2	4.44	49.3
Moisture Content (total wt) (%)	91.5	86.1-96.0	2.58	2.8
Volatile Matter (%)	66.2	57.2-74.3	5.01	7.6
Fixed Carbon (%)	24.8	17.3-29.4	2.60	10.5
Hydrogen (%)	5.3	4.6-6.0	0.32	6.0
Carbon (%)	51.7	43.1-55.2	2.22	4.3
Nitrogen (%)	2.3	0.5-3.8	0.87	37.8
Sulfur (%)	0.3	0.1-1.5	0.22	73.3
Oxygen (%)	31.3	24.4-40.6	3.86	12.3
Bulk Density (g/cc)*	0.10	0.05-0.15	0.03	30.0
pH (H_2O)*	5.5	4.0-6.9	0.86	15.6
pH ($CaCl_2$)*	4.4	2.9-5.9	0.95	21.6

* Analysis performed in MPIP laboratory.

TABLE 10

DOE ANALYSIS—HEMIC SAMPLES

	Average	Range	Standard Deviation	Coefficient of Variation
Btu/lb	8937	7686-9839	434.15	4.9
Ash Content (%)	10.2	3.5-24.7	4.20	41.2
Moisture Content (total wt) (%)	88.2	76.1-94.3	2.96	3.4
Volatile Matter (%)	62.7	49.9-71.8	4.20	6.7
Fixed Carbon (%)	27.1	20.6-38.0	2.11	7.8
Hydrogen (%)	5.2	4.2-6.0	0.36	6.9
Carbon (%)	52.2	44.0-55.7	2.21	4.2
Nitrogen (%)	2.6	1.0-4.1	0.55	21.2
Sulfur (%)	0.3	0.1-1.1	0.15	50.0
Oxygen (%)	29.5	22.5-36.7	2.49	8.4
Bulk Density (g/cc)*	0.13	0.06-0.28	0.04	30.8
pH (H_2O)*	5.5	3.8-6.5	0.64	11.6
pH ($CaCl_2$)*	4.6	3.0-6.0	0.73	15.9

* Analysis performed in MPIP laboratory.

TABLE 11

DOE ANALYSIS—SAPRIC SAMPLES

	Average	*Range*	*Standard Deviation*	*Coefficient of Variation*
Btu/lb	8356	7761-9192	388.18	4.6
Ash Content (%)	16.6	6.8-23.1	5.05	30.4
Moisture Content (total wt) (%)	84.3	78.3-90.7	2.94	3.5
Volatile Matter (%)	58.1	51.9-67.1	3.86	6.6
Fixed Carbon (%)	25.3	18.6-28.5	2.58	10.2
Hydrogen (%)	4.8	4.4-5.5	0.34	7.1
Carbon (%)	48.9	45.1-53.2	2.58	5.3
Nitrogen (%)	2.7	1.7-3.7	0.45	16.7
Sulfur (%)	0.7	0.3-1.5	0.45	64.3
Oxygen (%)	26.3	22.2-31.6	2.67	10.2
Bulk Density (g/cc)*	0.17	0.09-0.23	0.04	23.5
pH (H_2O)*	5.9	5.1-6.7	0.39	6.6
pH ($CaCl_2$)*	5.2	4.6-5.7	0.32	6.2

* Analysis performed in MPIP laboratory.

orange. Peatlands of variable depth are shown in an alternating pattern of light and dark orange. The black stipple pattern on peatlands designates peatlands covered by an accumulation of fibric sphagnum moss peat (raised bogs). Through the use of labels and contour lines, the areas of peat greater than 150 cm deep and the areas covered by sphagnum moss peat are further subdivided by depth. Mineral soil areas are displayed in gray.

On the map, total depth of peat is indicated by the following designations:

A	0-150cm	(~ 0- 5ft)
B	151-300cm	(~ 5-10ft)
C	301-450cm	(~10-15ft)
D	451-600cm	(~15-20ft)
AB	0-300cm	(~ 0-10ft)

The total depth designations (e.g., A) when used alone, denote a profile composed entirely of hemic peat. A total depth designation used in conjunction with a lower case letter indicates a hemic peat profile with a fibric moss peat cap or a profile composed entirely of sapric peat.

The fibric sphagnum moss peat cap unit is subdivided by depths:

a	20- 60cm	(~1- 2ft)
b	61-150cm	(~2- 5ft)
c	151-300cm	(~5-10ft)

The cap unit designations are always used with a total depth designation (e.g., Aa); the peat unit has a total depth indicated by the first letter (e.g., A 0-150 cm) and has a fibric sphagnum moss peat cap of the depth indicated by the lower case letter (e.g., a 20-60 cm). Hemic peat composes the rest of the profile.

The symbols Ax and Bx designate sapric peat areas on the map. The entire profile, with a total depth of A (0-150 cm) or B (151-300 cm) is a sapric peat.

The total depth unit AB represents a variable peat depth, 0-300 cm, composed of hemic peat. This unit is found in undulating terrain, such as within an end moraine, where peat depths change rapidly, making mapping difficult at the scale of the peat resource map.

The map provides locational information about Aitkin County peatlands and also a means for determining the areal extent and volume of peat in the county. The peat information from the map for Aitkin County was coded and stored in computer-readable form. From this information, the acreages of the various mapping units were determined. Volumes of peat were calculated by multiplying the areal extent by the average depth of each mapping unit. The quantity of oven-dried peat (in tons) was found by multiplying the volumes of peat by the average bulk density value determined for each peat type. These values were then multiplied by the average heating value for each peat type to determine the potential energy available from peat in the county.

Peatland Area

Peatlands cover 170,050 ha (420,160 ac) of a total area of 517,200 ha (1,278,000 ac) in Aitkin County. Hemic peat covers 149,460 ha (369,320 ac) of land, 88% of the peatland area. Sapric peat covers 17,210 ha (42,520 ac), 10% of the peatland area, and areas of hemic peat overlain by a fibric sphagnum moss cap cover 3,380 ha (8,320 ac), 2% of the peatland area.

Areas with peat accumulations greater than 150 cm deep cover 30,390 ha (75,080 ac), or approximately 18% of the total peatland area. The areal extent for each mapping unit is shown on Table 12.

Peat Tonnages

The total quantity of oven-dried peat in Aitkin County is 246,414,000 metric tons (276,237,000 U.S. short tons). Hemic peat comprises 221,541,000 metric tons (248,443,000 U.S. short tons), sapric peat 22,936,000 metric tons (25,664,000 U.S. short tons), and fibric peat 1,937,000 metric tons (2,130,000 U.S. short tons).

TABLE 12

AREAL EXTENT AND VOLUMES OF MAPPING UNITS IN AITKIN COUNTY, MINNESOTA

Map Unit	Peat Type	Percent Peat Area	Area ha	Area ac	Average Thickness cm	Average Thickness ft	Volume ha-cm	Volume ac-ft
Ax	Sapric	9.89	16,820	41,560	75	2.5	1,261,433	103,900
Bx	Sapric	0.23	390	960	225	7.5	87,750	7,200
A	Hemic	67.92	115,480	285,360	75	2.5	8,661,000	713,400
B	Hemic	13.94	23,700	58,560	225	7.5	5,332,500	439,200
AB	Hemic	4.27	7,260	17,920	150	5.0	1,089,000	89,600
C	Hemic	1.54	2,620	6,480	375	12.5	982,500	81,000
D	Hemic	0.24	400	1,000	525	17.5	210,000	17,500
Aa	Fibric				40	1.3	4,000	312
	Hemic				35	1.2	3,500	288
	Total	0.06	100	240	75	2.5	7,500	600
Ba	Fibric				40	1.3	68,000	5,460
	Hemic				185	6.2	314,500	26,040
	Total	1.00	1,700	4,200	225	7.5	382,500	31,500
Ca	Fibric				40	1.3	27,200	2,184
	Hemic				335	11.2	227,800	18,816
	Total	0.40	680	1,680	375	12.5	255,000	21,000
Da	Fibric				40	1.3	6,000	468
	Hemic				485	16.2	72,750	5,832
	Total	0.09	150	360	525	17.5	78,750	6,300
Bb	Fibric				105	3.5	30,450	2,520
	Hemic				120	4.0	34,800	2,880
	Total	0.17	290	720	225	7.5	65,250	5,400
Cb	Fibric				105	3.5	37,800	3,080
	Hemic				270	9.0	97,200	7,920
	Total	0.21	360	880	375	12.5	135,000	11,000
Db	Fibric				105	3.5	2,100	140
	Hemic				420	14.0	8,400	560
	Total	0.01	20	40	525	17.5	10,500	700
Bc	Fibric	0.02	30	80	225	7.5	6,750	600
Cc	Fibric				225	7.5	11,250	900
	Hemic				150	5.0	7,500	600
	Total	0.03	50	120	375	12.5	18,750	1,500
TOTAL			170,050	420,160				

The quantity of peat found in accumulations greater than 150 cm deep is 98,134,000 metric tons (110,012,000 U.S. short tons). Peat tonnages for each mapping unit are presented on Table 13.

Peat Energy Potential

The estimated energy potential for all peat deposits in Aitkin County is 4.91×10^{15} Btu (4.91 quads of energy). The estimated energy potential for peat deposits meeting the DOE fuel-grade criteria is 1.97×10^{15} Btu (1.97 quads of energy).

The estimated energy potential for peat deposits meeting the DOE fuel-grade criteria excluding fibric sphagnum moss peat, which has horticultural value, is 1.93×10^{15} Btu (1.93 quads of energy).

The estimated energy potential of the peat does not consider the amount of energy required to mine, dry, and process the peat and to convert the peat to usable energy. Table 14 is a summary of the quantity and energy potential of peat in Aitkin County.

TABLE 13

PEAT TONNAGE (OVEN-DRIED) PER MAPPING UNIT IN AITKIN COUNTY, MINNESOTA

Map Unit	*Peat Type*	*Metric Tons (×1,000)*	*U.S. Tons (Short) (×1,000)*
Ax	Sapric	21,444	24,001
Bx	Sapric	1,492	1,663
A	Hemic	112,593	126,272
B	Hemic	69,323	77,738
AB	Hemic	14,157	15,859
C	Hemic	12,773	14,337
D	Hemic	2,730	3,098
Aa	Fibric	40	42
	Hemic	46	51
	Total	86	93
Ba	Fibric	680	743
	Hemic	4,089	4,609
	Total	4,769	5,352
Ca	Fibric	272	297
	Hemic	2,961	3,330
	Total	3,233	3,627
Da	Fibric	60	64
	Hemic	946	1,032
	Total	1,006	1,096
Bb	Fibric	305	343
	Hemic	452	510
	Total	757	853
Cb	Fibric	378	419
	Hemic	1,264	1,402
	Total	1,642	1,821
Db	Fibric	21	19
	Hemic	109	99
	Total	130	118
Bc	Fibric	68	81
Cc	Fibric	113	122
	Hemic	98	106
	Total	211	228
TOTAL		246,414	276,237

NOTE: Computed using fibric peat at 10 metric tons/ha-cm (136 U.S. short tons/ac-ft), hemic peat at 13 metric tons/ha-cm (177 U.S. short tons/ac-ft), and sapric peat at 17 metric tons/ha-cm (231 U.S. short tons/ac-ft).

SUMMARY

Over 700 sites were visited by the MPIP to determine peat type and depth. Samples were obtained from 188 selected representative sites for MPIP laboratory analysis. Samples from 52 of these sites were also sent to the DOE laboratory for energy-related analysis.

Peatlands cover 170,050 ha (420,160 ac) or 33% of the total area of Aitkin County. Total oven-dried tons of peat amount to 246,414,000 metric tons (276,237,000 U.S. short tons).

The peatlands meeting the DOE criteria for fuel-grade peat cover 30,390 ha (75,080 ac) or 18% of the county's total peatland area. The quantity of peat in these peatlands is 98,134,000 oven-dried metric tons (110,012,000 oven-dried U.S. short tons). These peatlands cover at least 80 contiguous acres and are composed of peat that (1) has an average energy value of 8,874 Btu/lb (moisture-free), (2) has an average ash content of 10.6%, and (3) is at least 150 cm (~5 ft) deep.

The estimated potential energy of these peat deposits is 1.97×10^{15} Btu (1.97 quads of energy) if all three peat types, fibric, hemic, and sapric, in deposits greater than 150 cm deep are considered.

TABLE 14

QUANTITY AND ENERGY POTENTIAL OF AITKIN COUNTY PEAT

	Hectares	*Acres*	*Tons-Dry Metric (×1,000)*	*Tons-Dry U.S. Short (×1,000)*	*Btu's*	*Quads**
By Depth						
≥150cm Deep	30,390	75,080	98,134	110,012	1.97×10^{15}	1.97
<150cm Deep	139,660	345,080	148,280	166,225	2.94×10^{15}	2.94
TOTAL	170,050	420,160	246,414	276,237	4.91×10^{15}	4.91
By Type						
Fibric			1,937	2,130	0.04×10^{15}	0.04
Hemic			221,541	248,443	4.44×10^{15}	4.44
Sapric			22,936	25,664	0.43×10^{15}	0.43
TOTAL			246,414	276,237	4.91×10^{15}	4.91

* One Quad = 1×10^{15} Btu.

APPENDIX A

LABORATORY METHODS

Moisture Content

To determine moisture content, an as-received sample was weighed, oven-dried to a constant weight (105°C for ~24 hrs), cooled, and reweighed. Moisture content expressed as (1) a percentage of total weight represents the moisture present in the soil, and as (2) a percentage of dry weight represents the water-holding capacity of the soil. Moisture content was calculated as follows:

$$\text{Total wt., percent} = [(A - B) \times 100]/A$$

$$\text{Dry wt., percent} = [(A - B) \times 100]/B$$

where:

A = grams of as-received sample, and
B = grams of oven-dried sample.

Bulk Density

To determine bulk density, an as-received sample of known volume was oven-dried to a constant weight (105°C for ~24 hrs), cooled, and weighed. Bulk density was calculated on an oven-dry weight—wet bulk volume basis as follows:

$$\text{Bulk density, g/cc} = B/C$$

where:

B = grams of oven-dried sample, and
C = volume in cc of as-received sample.

Ash Content

To determine ash content, an oven-dried sample (from moisture determination) was thoroughly mixed in a blender. A one-gram portion was placed in a crucible, ignited in a muffle furnace (500°C for 1 hr), cooled, and reweighed. Ash content was calculated as follows:

$$\text{Ash, percent} = (D \times 100)/E$$

where:

D = grams of ash, and
E = one-gram of oven-dried and mixed sample.

pH

The pH of peat was measured in (1) a suspension of deionized H_2O and (2) in a suspension of 0.01M $CaCl_2$ solution. The procedure for both measurements involved lightly packing 15 cc of an as-received peat sample into a 100 cc container, adding 15 cc of solution, and mixing. Each suspension was set aside for an hour to equilibrate before measuring with a pH meter.

pH was measured both in water and in a calcium chloride solution because the pH readings in water can be modified by salts, whereas the observed pH in calcium chloride solution is virtually independent of the initial amount of salts present in the soil (ASTM 1971). Calcium chloride suspensions are almost independent of dilution because of the release of hydrogen ions through cation exchange, whereas water suspensions have a greater dilution effect, resulting in a slightly higher pH value (Canada Soil Survey Committee 1976).

Proximate and Ultimate Analyses

Proximate and ultimate analyses were performed by the DOE Coal Analysis Laboratory using standard ASTM laboratory procedures.

GLOSSARY

Btu. British thermal unit, the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

Clay. As a soil separate, the mineral soil particles less than .002 mm in diameter. As a soil textural class, soil material that is 40% or more clay, less than 45% sand and less than 40% silt.

Crown cover. The amount of plant surface that covers the ground as viewed from above, expressed as a percentage of the total possible (100%) or of a particular group, e.g. black spruce crown cover of about 50%.

Ericaceous. Belonging to the family Ericaceae. Plants of the heath family, including bog rosemary, leatherleaf, Labrador tea, and swamp laurel.

Evapotranspiration. The total amount of water taken into the atmosphere by evaporation from the surface and from the transpiration of living plants.

Fibric peat. The least decomposed of peat types. It contains large amounts of fiber which is well preserved, and its botanical origin is readily identifiable.

Glacial drift. All rock material (clay, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier.

Ground cover. Low growing plants such as mosses that form a dense layer on the ground surface.

Hemic peat. The moderately decomposed peat type which is partly altered physically and chemically. Fibers are largely destroyed when rubbed and are less easily identified than in fibric peat.

Humus. The more or less stable fraction of the organic soil matter remaining after the major portion of plant and animal residue has decomposed. Usually dark in color.

Limnic materials. Materials deposited in lakes. These materials are primarily chemical and biological precipitates (plants and animals).

Loam. The textural class name for soil having a moderate amount of sand, silt, and clay. Loam soils contain 7% to 27% clay, 28% to 50% silt, and less than 52% sand.

Lobe, glacial. One of the lobate protrusions of the margin of an ice sheet.

Microrelief. Relief of a peatland surface from the top of hummocks or ridges to the bottom of hollows.

Mineralization. The conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.

Moraine. An accumulation of material which has been transported or deposited by glacial ice. Moraine material is usually an ungraded mass of sediment ranging in size from clay to boulders.

pH. A numerical symbol for the degree of acidity or alkalinity of a solution. A pH value of 7 indicates a neutral solution; pH values of 0 to 7 indicate decreasing acidity, and values from 7 to 14 indicate increasing alkalinity.

Profile, soil. A vertical section of the soil through all its horizons and extending into the parent material.

Sand. Individual rock or mineral fragments in soils having diameters ranging from .05 to 2 mm. The textural class name of any soil that contains 85% or more sand and not more than 20% clay.

Sapric peat. The most highly decomposed peat. An amorphous mass consisting largely of humus. Fibers, except for the larger ones, are not identifiable.

Silt. Individual mineral particles that range in diameter from .002 mm to .05 mm. Soil of the silt textural class is 80% or more silt and less than 12% clay.

Soil. A naturally occurring, unconsolidated material on the earth's surface that has been influenced by parent material, climate, microorganisms, and topography, all acting through time to produce soil that may differ from the material from which it was derived in many physical, chemical, mineralogical, biological, and morphological properties.

Stratigraphy. Science dealing with the formation, composition, and correlation of stratified sequences.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil.

Till. Unstratified and unsorted glacial drift deposited directly by the ice and consisting of clay, silt, sand, gravel, and boulders intermingled in any proportions.

Understory. A layer of foilage in a forest beneath the crown cover and above the ground cover.

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