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FACTORS AND PROBLEMS IN THE SELECTION OF PEAT LANDS FOR DIFFERENT USES

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INTRODUCTION

It is estimated that approximately 79,000,000 of the 113,537,000 acres of wet land in the United States are of potential economic importance.[1] The question whether the utilization of these peat lands is economically practicable is of special interest in the States bordering the Great Lakes and those on the Gulf Coastal Plain, and the rest of the country, concerned with the growing needs of a growing population, is showing an increasing interest in the problem.

For an economically sound solution of the problem, agriculture and other industry must have a fuller knowledge of the nature of the peat lands and must deal with them according to that knowledge. It is essential that the problem be seen as a whole, or at least broadly, so that the relationship among the various conditions and factors which must be coordinated and controlled in the future utilization of the peat lands may be understood.

Just what type of peat area shall be used is often more important than the choice of the surface material. It is equally clear that in any particular case the selection depends upon several factors, among which the general economic considerations taken into account are frequently only the more obvious ones. On the other hand, the profile features of the peat area, the stage of disintegration of the

[1] The acreage of peat land was much larger at an earlier time, but with the settlement of the States many extensive areas of shallow peat that were long under cultivation have now disappeared. Only black-colored mineral soils with a high humus content remain to-day to suggest the former locations of such areas.

different layers, and the condition of the water supply and of the mineral substratum are seldom examined. For this reason there has always been a certain element of hazard and doubt in the economic development of peat resources.

Experience in the United States appears on the whole to be in accord with that reported for Europe. From many peat lands under cultivation the returns in vegetables, forage crops, or small grains have been disappointing, although for unknown reasons on occasional fields excellent crops have been raised. Some peat lands are easily tilled, increase the quality of timber produced, supply a material which yields a satisfactory artificial manure upon composting, or carry a roadbed designed for heavy traffic, while other peat areas are not giving promising results. To remove the element of doubt, or at least to reduce it, is the purpose of this bulletin. Briefly, the object is to formulate a basis for a more definite selection and also for a safer and more economic procedure in the work of improving, for different uses, peat lands which have been abandoned in various sections of the country.

EXAMINATION OF PEAT LANDS

In order to determine the class to which any peat-land unit belongs a systematic examination of the fundamental factors is required. Undue stress has often been laid on the color of the peat material, the acid reaction, or the native surface vegetation, as the factors which indicate the type of land to be chosen for development. In many instances, farmers have failed because the peat area did not produce according to expectations based on surface conditions. The observed failures are now well understood to be due to inexperience as to the widely varying essential differences between peat lands, each case requiring more or less special examination; and, in consequence, efforts are now being directed toward working out a more dynamic and geographic basis for correlating the possibilities and limitations of peat lands. The aim is to prevent the difficulties at their source, rather than to adopt doubtful corrective measures. It is therefore of considerable importance to supplement in various ways the general observations upon peat and muck, with more detailed descriptions of the whole profile and of certain outstanding factors, such as the sources of ground water and mineral subsoil. Upon information concerning these factors an intelligent estimate of peat areas may be based.

A field method to establish a natural classification of peat lands has now been used over a section of this country large enough to lead to wide general views. Directions for a uniform method to be followed have been published under the title "The Stratigraphic Study of Peat Deposits" (*11*).[2] As a supplementary aid to this subject a series of investigations limited to restricted regional areas has been made (*9, 14, 15*), and others are in progress. These studies are not without interest to those who are working on the nomenclature and mapping of peat lands, on comparative researches in general soils science, and in geology and ecology.

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[2] Serial numbers (italic) in parentheses refer to "Literature cited," at the end of this bulletin.

In selecting a peat-land area, two lines of procedure demand careful attention, and they should be followed as far as possible for the particular area under consideration. In the preliminary observations as to the quality of the peat land and its layout a survey is made which covers the points outlined on the tally sheet in the publication cited above (*11*). If the reconnaissance study indicates that the area is probably suitable for the intended use to be made of it—e. g., systematic field experiments and research, settlement, reforestation, or production of stable litter and peat composts—the final investigation should be made with great care and more in detail.

If the area shows desirable qualities for the particular purpose—the manufacture of peat litter, for example—the size of the tract should be outlined, its levels determined, and a map prepared showing acreage, boundaries, roads, elevations, outlet and fall of drainage waters, character of the vegetative cover, topographic features of the adjacent land, and the distance to main transportation facilities.

It is not generally recognized that careful scrutiny should be extended also to the structure of the entire peat area. In most cases of failure, the failure has been due to the fact that the importance

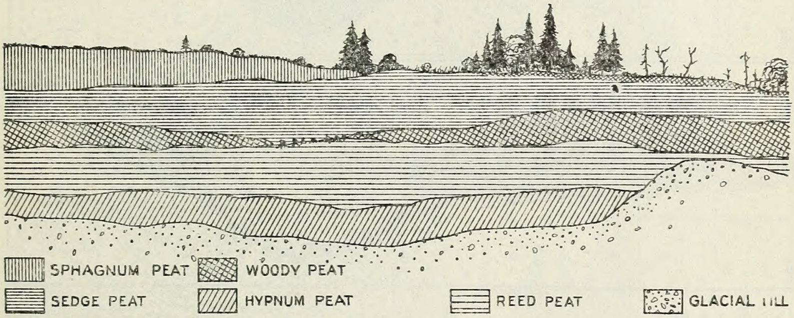


FIG. 1.—Profile of a peat-land area which developed under changing environmental conditions. The ground-water level became elevated with the gradual accumulation of plant remains. The different layers of peat not only reveal the nature of the former vegetation which yielded peat but also offer a basis for an analysis of the adverse external factors that tended to modify the conditions of plant growth.

of test holes was not understood or taken into account. Profile soundings indicate the nature of a peat area. For all specific purposes, samples of peat should be collected at each corner of sectional divisions which range from 100 to 300 feet or more in length. These samples should be obtained from different depths in order to ascertain more accurately any marked changes in pulpy, fibrous, or woody materials. This is important, not only in the comparison of peat layers but of peat areas. The amount of decomposition of each layer may be determined readily by the foodstuff method of analysis (*12*). This method permits a quantitative distinction between the different proportions of the undecomposed, resistant, crude-fiber fraction in a peat material and of the altered, nonfibrous fraction of organic material. These data will assist in drawing the isopachic lines that connect points at which the thickness of the several peat layers is measurable (figs. 1 and 2). A chart of this kind will indicate graphically the profile of the entire area; that is, the position, continuity, and quality of the different types of peat. It will be of value, also, as a guide in mapping such land. The final map of the area should show clearly the distribution and boundary lines of the different type profiles. It should designate each unit by a symbol, letter, or special color, particularly the areas difficult from any cause to prepare for development, also the units recommended for suspension or proposed to be excluded. Charts and maps of this nature aid not only in making estimates of acreage and quantity of raw materials available for different uses, but they are useful in agricultural surveys and statistics. For practical application, the stratification of peat land may be applied to a number of different objectives, such as the classification of peat soils forming in the surface layers, the interpretation of results from similar areas of peat

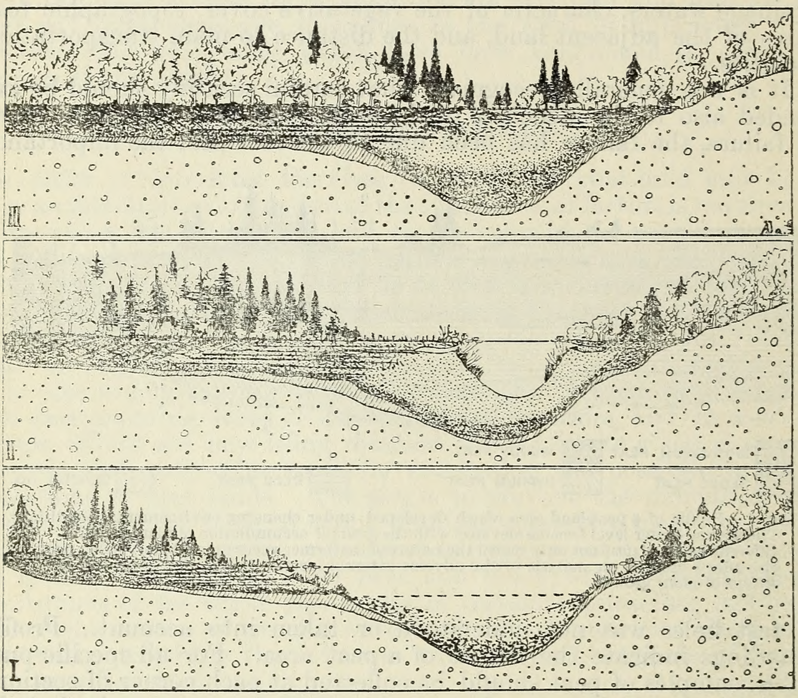


FIG. 2.—Graphic presentation of stages in the formation of a peat deposit over a depression that contained an older body of standing water. Compare with Plate 2. Adapted from Dachnowski (*6*), arranged in reversed order

in different localities, or the comparison of European and American peat lands.

An index number has been used in field work to designate each type unit of peat-land profiles. It is especially useful for indicating the relative order and character of the chief layers of peat with respect to the mineral substratum. To visualize the structural framework correctly, peat-land profiles must be read upward (pl. 1). It should not be assumed, however, that this system of nomenclature is adequately descriptive, because the type profile of a unit area of peat may show variable characteristics of thickness, texture, color, and stage of disintegration. The variations are very numerous and constantly changing, particularly in drained peat lands the surface layers of which are under cultivation. For types of peat land in which soil-forming processes have become definitely established and horizons have appeared at different ranges of depth, the name of the locality

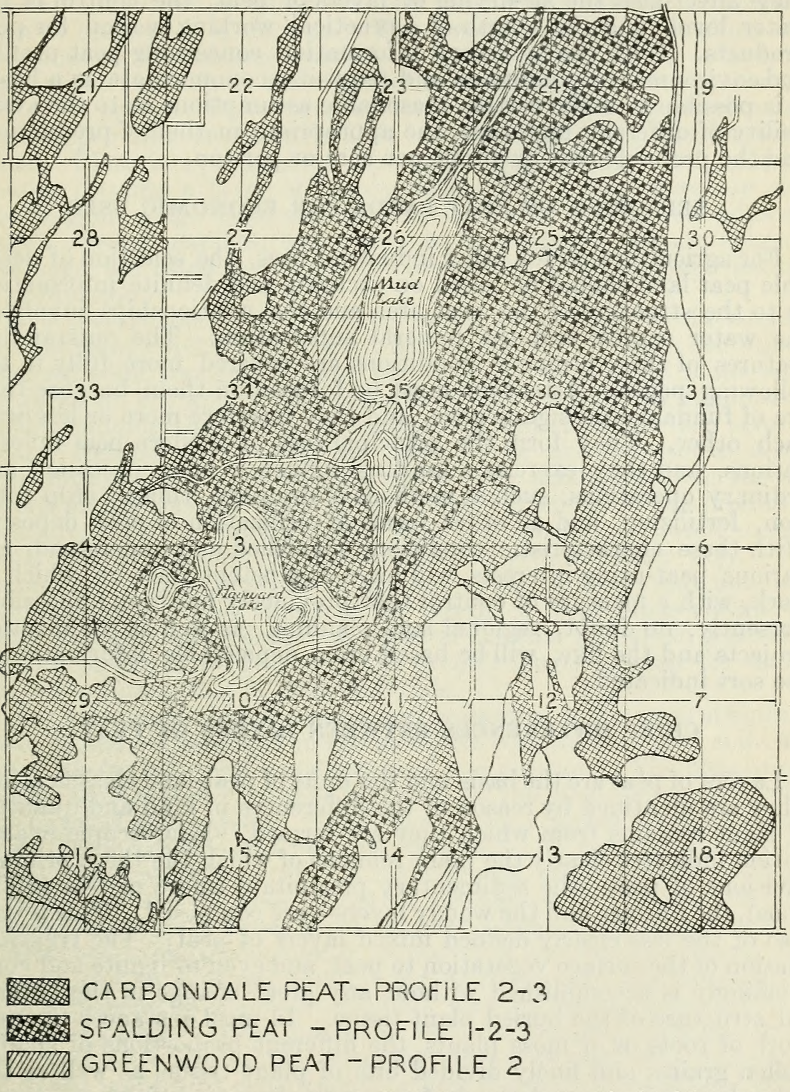


FIG. 3.—Specimen map of an area to show the distribution of types of peat land and the nomenclature employed to designate them. Each pattern represents a specific profile by which the characters of the peat area have been distinguished. (Courtesy of Michigan Land Economic Survey in cooperation with the Bureau of Plant Industry)

where these differences were first observed may be assigned to the index number of the type unit. A specimen map is given in Figure 3. Each pattern indicates the specific profile, shown in Plate 1, by which the character of the individual peat areas have been distinguished.

The use of key letters, indicated in Plate 1, with numbers corresponding to the thickness of each layer, would serve a similar purpose.

Attention also needs to be given to rainfall and general climatic conditions. Weather and climate influence not only the growth of crops and a variety of plant diseases common to peat lands, but they affect also the air-drying of layers of peat, the control of the water level, and the length of a practical working season for peat products. With the necessary information concerning peat profiles and environmental conditions and requisite economic data as a basis, it is possible to make certain reasonable assumptions as to the availability of different materials, the appropriate method of production, and the probable cost or profit per acre or per ton.

SELECTION OF PEAT LANDS FOR ECONOMIC USES

For agricultural as for other industrial uses, the selection of desirable peat land should be based on accurate and definite information as to the structure of the peat area and the relationships involving the water supply and the mineral substratum. The outstanding features of these principal conditions are covered more fully in the following pages. Attention must be focused on them because they are of fundamental significance, and they interfere more or less with each other. They form the principal task of modern peat investigations, and they exercise a limiting influence upon necessary and ordinary operations, such as methods of drainage, tillage, crop rotation, fertilizing, and all other forms of utilization of peat deposits. With these characteristic conditions identified and understood, the various peat-using interests will have competent data on which to work, with a measure of control that previously has been impossible. Presently, no doubt, regional land planning, as well as colonization projects and the like, will be based upon dependable information of the sort indicated.

CHIEF DIFFERENCES BETWEEN LAYERS OF PEAT

Layers of peat are the basis and the units of peat-land classification. They are identified by reason of the differences in kind and quantity of plant remains from which they are formed. Microscopic examination indicates clearly the plant remains of which the three primary divisions of peat—the sedimentary precipitate (more or less gelatinous), the fibrous, and the woody layers—are composed. This is true also of the less clearly defined mixed layers of peat. The transformation of the surface vegetation to peat, and even to lignite and coal, seemingly is accomplished without any great change in the botanical structure of the buried plant tissue. In most instances the network of roots or of moss plants, the different proportions of spores, pollen grains, and finely divided bits of plant tissue, as well as the cuticular, resinous, and woody fragments of varying sizes, are found well preserved in the respective layers of peat. The evidence of European investigators as to the development of forests in postglacial times is based on the method of quantitatively analyzing the pollen grains identified in different peat materials.

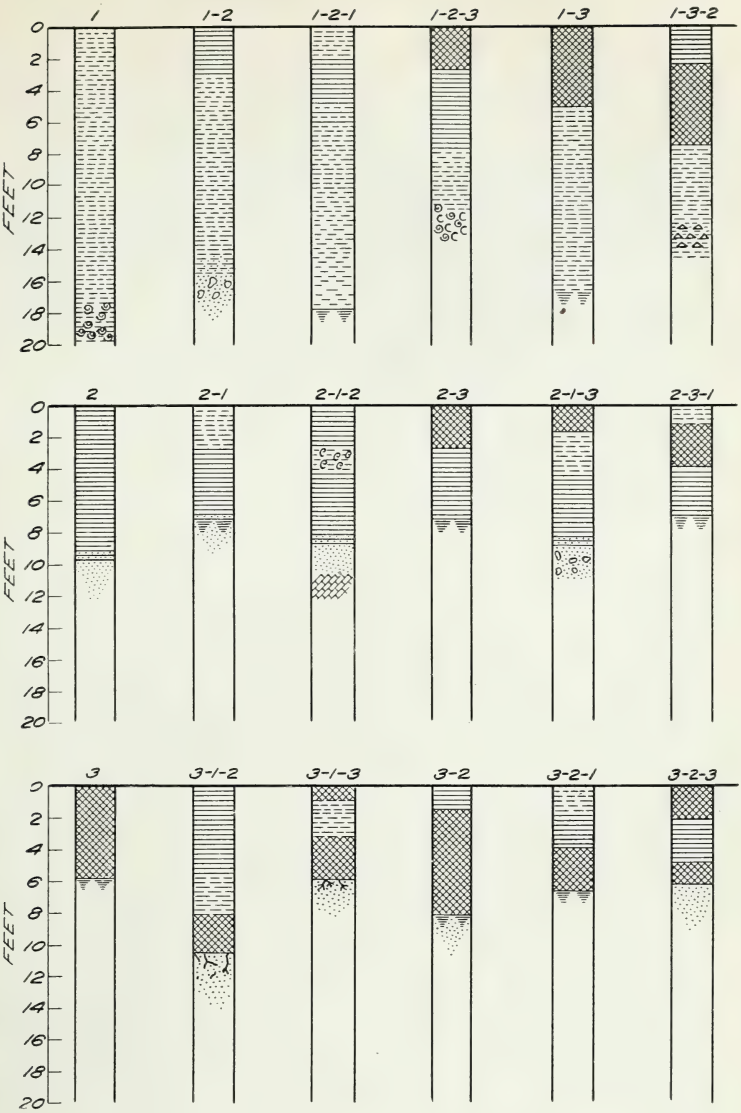
According to their origin, layers of peat represent the plant remains of social units of vegetation. They are distinctive products from plant associations which varied according to climate and occupied ponds or formed marshes and swamp forests (pl. 2; also fig. 2). Plate 2, *A*, illustrates aquatic vegetation forming a layer of fine-textured peat by sedimentation in open water. The marginal sedge marsh gives rise to a layer of fibrous radicellate peat material. Plate 2, *B*, shows a sphagnum bog from which a layer of coarsely fibrous moss peat is derived. The dwarfed growth of conifers is a reaction to the adverse conditions for trees rooting in a layer of sphagnum peat; it is difficult for tree seedlings to become established in coarsely fibrous types of material. The remnant of a former larger lake is shown, which is nearly filled with sedimentary peat. Plate 2, *C*, represents a swamp forest of tamarack and red maple, forming a layer of woody peat. The young trees are seen growing on sedge peat well above the water level of an adjacent pond. Sedge marshes, when they have reached a certain stage of drainage, are often very rapidly covered by forest through natural reproduction.

The several social groups of vegetation were related to the edaphic environment chiefly with regard to the general moisture conditions. Mineral soils, topography, and successional relations of plant communities do not appear to have been of any considerable significance in determining the character, continuity, and thickness of a layer of peat. Neither do these factors account for the number of layers superimposed upon one another or for their arrangement in the different profile classes of peat areas. The variations in the profiles of peat areas seem to show a much closer relationship to climatic conditions and consequent changes of level in ground water (*14*). The formation of peat deposits in ancient times probably has not been very different. The thickness or depth of peat areas within the older morainal belts, as well as those of the coal periods in general, is greater, it seems, by reason of the greater length of time for undisturbed accumulation of peat materials.

The individual characteristics and properties of the several kinds of peat, in the original and in the modified condition as peat soils, are traceable to their respective botanical composition. The dimensions of the plant remains may be regarded as the most important point for physical comparison. They concern the relation between coherence or consistency and moisture content. As regards organic material the proportions of the nitrogenous and carbonaceous, the lignose, cellulose, pentose, and other substances, the fibrous and nonfibrous fractions of a peat layer, account quantitatively for chemical differences. The physiological properties of this class of organic substances rest on a special relationship to plants and microorganisms, which depends in the most intimate way on the nutritive value of the compounds. It has not been fully determined to what extent and in what condition the respective layers of peat may serve as a source of plant-food constituents or how humus is formed from them. There is already considerable information on the physical and chemical characteristics of the several kinds of peat. Some of the outstanding data have been tabulated in papers which deal with the quality and value of important types of peat (*8*, *12*). Photographs that aid in the identification of different layers of peat are shown in Plates 3 to 6. Knowledge of these materials would be greatly advanced, however, if analytical and experimental work upon them could be made by uniform methods. To be definitely useful for practical purposes the data need to be systematized. The differences of various peat layers and their corresponding effects upon agricultural and industrial operations should be expressed on a common basis for comparison.

Varieties of the jellylike, sedimentary layers of peat are shown in Plate 3. They are also designated by the digit 1 in the profile series in Plate 1. Of the specimens shown in Plate 3, sample *A* represents a dark-brown, fine-textured, moist, sedimentary peat over a bed of shells and Chara marl. The plant remains are of microscopic size and in varying states of preservation. The predominant organic constituents are derived from aquatic vegetation, plankton, pollen, spores, and from the degradation of woody and resinous tissues. Plate 3, *B*, shows an air-dried pulpy peat of sedimentary origin which contains iron salts in varying concentrations. It is not uncommon to find an abundance of calcium-sulphate crystals in the material of some unproductive peat areas. This condition is shown in Plate 3, *C*, an air-dry, dark reddish brown sedimentary peat. The clusters of calcium-sulphate crystals were formed by the neutralization with ferrous sulphate and sulphuric acid with lime. These two substances are oxidation products of marcasite (iron sulphide or pyrites). Plate 3, *D*, shows a bluish green, orange, and maroon colored, plastic moist peat, embedded in shells and Chara marl. This material is not an important constituent, either of existing open-water deposits or of sedimentary types of peat; it is found as a surface layer under shallow open water, and contains gelatinous nodules formed by colonies of blue-green algæ. A few pollen grains, diatoms, and attrite organic débris of dark-brown color are present. Plate 3, *E*, represents an air-dry, blackish brown, rubbery, colloidal peat of sedimentary origin, showing cracks from irregular shrinkage. The plastic material contracts into a dense and hard mass as the moisture content diminishes by evaporation. It rarely splits along definite horizontal lines, but breaks up usually with a conchoidal or subconchoidal fracture. Plate 3, *F*, is typical of a mixed phase of fine-textured, sedimentary, air-dry peat, with embedded fibrous material derived from reeds. These mixtures are capable of holding appreciable quantities of unfree water and under suitable conditions tend to hasten decay. Some of the layers are noteworthy because they contain quantities of microscopic siliceous material from diatoms and sponge spicules. These are popularly known as itchy muck.

Sedimentary types of peat consist mostly of a fine-textured, nonfibrous fraction of organic matter. They have a high absorbing power for soluble salts and retain large quantities of unavailable water. This probably explains their colloidal character, more or less elastic when the moisture content, diminishing by evaporation, reaches a definite critical stage. Water-soaked layers of sedimentary peat material give way under pressure; but when drained they contract more and more into a dense mass, becoming hard upon air drying. Because of the irregular shrinkage, a sedimentary layer may show vertical cracks and fissures. When exposed to alternate moisture and drying, it crumbles and assumes a granular form. A moderate proportion of this finely divided material embedded in fibrous or woody layers of peat serves as a binder, giving additional compactness.



KEY TO LETTERS, NUMBERS AND SYMBOLS

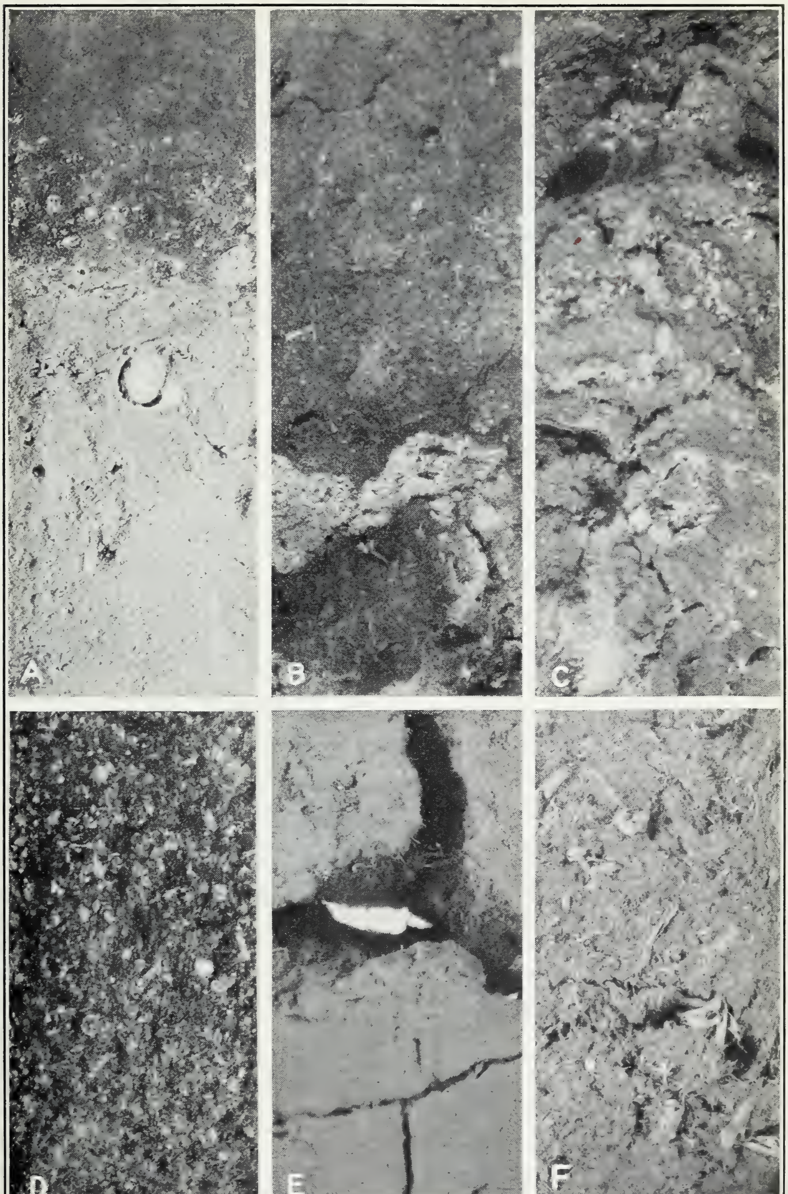
Material	Letter	No.	Symbol	Material	Letter	No.	Symbol
Woody Peat	W	3		Marl, chara.	M		
Fibrous Peat	F	2		Marl, shell	M		
Pulpy Peat	P	1		Diatoms	D		
Sand	S			Gravel	G		
Clay	C			Bed Rock	R		

GENERALIZED CROSS SECTIONS SHOWING SERIES OF THE MORE COMMON TYPE PROFILES OF PEAT LANDS

The structural framework when properly analyzed serves a very concrete and practical purpose. Profile sections bring out the conditions under which drainage, cultivation, systems of farming, reforestation, and the construction of highways on peat land take place. Adapted from Dachnowski (*11*)

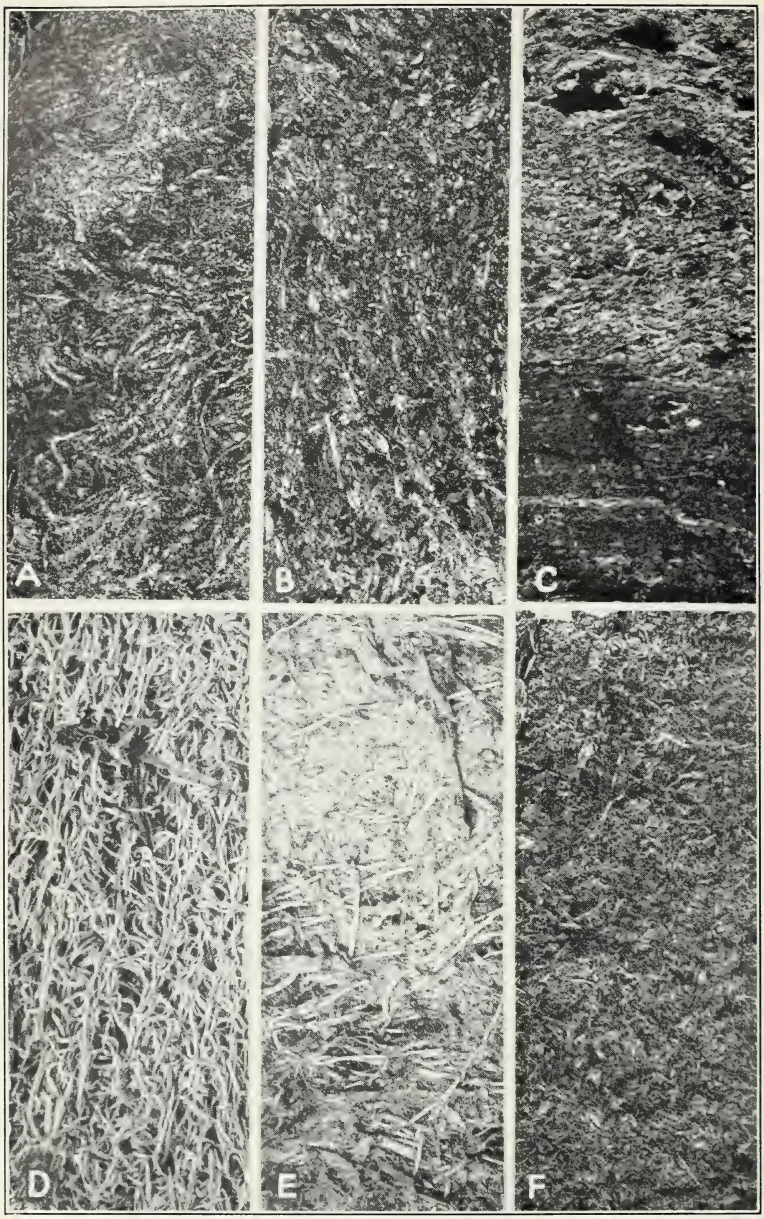
TYPES OF PEAT-FORMING VEGETATION

These illustrate the formation of *A*, sedimentary (photographed by L. R. Schoenmann); *B*, fibrous (photographed by H. R. Sayre); and *C*, woody layers of peat



VARIETIES OF SEDIMENTARY PEAT

A, Over shell marl; *B*, with iron salts; *C*, with calcium-sulphate crystals; *D*, algal; *E*, colloidal; *F*, mixed phase. (All natural size)



VARIETIES OF MOSS PEAT

A, Hypnum peat; *B*, partly disintegrated; *C*, over sedimentary material; *D*, sphagnum peat; *E*, partly fibrous; *F*, partly disintegrated. (All natural size from air-dry samples)

Fibrous layers of peat, shown in Plates 4 and 5, are porous and more or less resistant; they stand up well in vertical-walled ditches and excavations, yielding slowly to frost action and decomposition. In the profile series of Plate 1 the layers are designated by the digit 2. Plate 4, *A*, shows an air-dry sample of rusty brown fibrous hypnum peat, spongy and poorly decomposed. The outline of the plant remains is fairly clear and distinct, and the material contains scarcely any of the altered nonfibrous fraction of organic material which is characteristic of more advanced stages of disintegration. Plate 4, *B*, represents a dark-brown hypnum peat, partly disintegrated, in which the individual plants and their structure are more or less discernible to the eye. Plate 4, *C*, illustrates the side view of an air-dry sample of hypnum peat, reddish to yellowish brown, partly fibrous, resting on a layer of fine-textured sedimentary peat with shells. Distinguishing characteristics of sphagnum peat are shown in Plate 4, *D*. The material is light brown, coarsely fibrous, spongy, and most of the plant remains are very well preserved. In Plate 4, *E*, the characteristic structure of the sphagnum mosses is still recognizable, and in Plate 4, *F*, the brown air-dry sphagnum peat shows a crumbly texture, owing to the more advanced stage of disintegration. The proportion of the undecomposed "crude-fiber" fraction of organic matter is still rather high in this material.

Varieties of sedge and reed peat are shown in Plate 5: *A*, Sedge muck from a dark-brown, disintegrating fibrous sedge peat, after one year of cultivation under natural field conditions; *B*, typical sample of the dark-brown, finely fibrous, felty sedge peats, showing radicellate structure; *C*, an air-dry, brown, coarsely fibrous, spongy sedge peat, poorly decomposed, representing the underground stems and roots of sedges which spread over a lake or pond after having floated as a mat of varying thickness on the surface of the water; *D*, a blackish brown, well-disintegrated reed peat, granular after five years under cultivation. It will be noted that the proportion of the altered nonfibrous fraction of organic material is very large in this reed muck. The underground untilled portion of a reed peat is shown in Plate 5, *E*. This material represents a dark-brown, partly fibrous reed peat in which the plant remains are more or less clearly discernible. Fungal hyphæ are often present, but they form an unimportant proportion of the mass. It is not uncommon, however, to find a still more fibrous material at lower depths below the surface. Plate 5, *F*, represents a yellow-brown, coarsely fibrous reed peat, rather spongy and very poorly decomposed. The material is easily identified by the characteristic structure of the nodes and its wavy internodes.

It is not generally understood that fibrous layers of peat, whether derived from mosses (pl. 4, *A* and *D*) or from the roots and underground stems of sedges and reeds (pl. 5, *C* and *F*), should be subjected to maceration or to the alternation of moisture and moderate drying. Such layers must be changed to muck and humus stages by means of aeration, freezing, and the activity of microorganisms. Variations in the content of finely fibrous, felty, or carbonized material and mixtures of fibrous with sedimentary peat tend to hasten decay, whereby favorable biochemical reactions for plant growth are created. A very serious problem is presented by the blowing of the dustlike surface muck derived from decomposing mixed and fibrous types of peat. This can be practically solved through the protection afforded to crops by shrubs or trees planted as windbreaks and shelter belts, by crop rotations, by irrigation, or by proper cultural treatment of the wind-swept muck soil.

Layers of woody peat (pl. 6 and digit 3 in the series of profiles in pl. 1) consist partly of granular, well-disintegrated organic material and partly of irregular-shaped woody fragments which have resisted the decomposing action of air and microorganisms. Plate 6, *A*, shows a profile section of an area of woody peat derived from a coniferous swamp forest. The layer represents dark-brown, moderately well-disintegrated granular material, as well as coarse woody fragments from the stumps and roots of trees. The moisture content of the underlying mineral soil was sufficiently low during the period of formation to favor the growth of trees and a fair degree of decomposition of the plant remains. The ground-water level became elevated in time, with the gradual accumulation of the peat material. Plate 6, *B*, shows a sample more or less typical of brown, laminated, poorly decomposed, woody peat derived from shrubs. The lamination, perhaps, is annual. Plate 6, *C*, represents a dark-brown, largely disintegrated woody peat derived from a swamp forest. This air-dry sample reveals a varying proportion of granular material and woody fragments.

The growth of forest trees causes a greater humification of the peat material containing the living roots, which in turn gives rise to the formation of soluble organic and mineral substances. Because of this varying rate of decay, a layer of woody peat may show a banded or bedded appearance and a critical water content differing accordingly.

In the raw state all types of peat of whatever stage of previous disintegration have a low value as nutritive constituents. When surface peat soils are removed from a cultivated area, as in the case of certain industries which dispose of peat for fertilizer purposes, the exposed underlying brown and yellow-brown peat material is detrimental to crops, at least for a period. Dwarfing of root systems and cessation of plant growth appear to be partly due to the lack of soluble nitrogen in the large supply of carbonaceous matter. Investigations bearing on the nitrogen supply in peat materials have proved that the content of organic nitrogen is not available for crops. In the absence of any adequate balance between carbonaceous materials and soluble nitrogen, deficiencies must be made up by manuring or fertilizing. When properly aerated, cultivated, and mineralized, the change from the peat stage to a material resembling humus may take place rapidly (pl. 5, *A* and *D*).

The fixation of atmospheric nitrogen by bacteria might be one of several methods to measure the nutritive value of different types of peat or of different stages of decomposition. It is doubtful, however, whether a layer of peat which has reached a mature stage of disintegration in the field is in consequence more productive. Attention should be focused not so much upon the stage of decay but rather upon the conditions, including the character of the layers below the surface, which are antagonistic or associative in the continuance of the soil-forming process. Field observations on the size and abundance of trees present in undrained swamp forests may be cited here to illustrate the complexity of this subject. A series of measurements (*6, p. 319*) upon the growth and yield of scrubby as well as of large timber indicated that the volume of wood produced varied periodically. The distribution of the timber showed no relationship to the depth of the peat area or to a specific type of peat material. A condition which lowered the quality and height of trees appeared to result when the peat material in the rooting zone had too high a water content for any length of time. The excess of water was probably a contributing rather than a direct factor in the variables which affected the quality of timber.

From the profile soundings it was finally established that with an increasing density in the stand of timber the stability of the structural framework below the surface peat layer was seriously impaired, causing the wooded area to sink irregularly (pl. 7, *A*). For this reason a clear understanding must be had of the carrying capacity of the underlying layers of peat. To make artificial reforestation reasonably profitable in the near future, careful attention should be paid to the complicated effects of a load placed on the surface of certain types of peat land.

EFFECT OF STRUCTURAL FEATURES OF PEAT LANDS

It would be interesting to illustrate by means of specific examples the fundamental relationship which exists between the position of the chief layers of peat and the origin and nature of a peat-land area. Local and regional peat deposits and those of foreign countries offer to the student of peat investigations an abundance of records for analysis, correlation, and interpretation. They will bear careful study, since the advantage rests with areas whose structural framework it would clearly be best to choose for special forms of peat-land utilization.

An added and very significant interest would be given by the consideration of such matters as the history of peat lands in the Northern and Southern Hemispheres, connecting this more definitely with the underlying terrestrial or cosmic causes of structural differences between areas of peat. In plans of peat investigations for the future, the new efforts need to be organized on a basis which will commend itself to science as well as to outstanding agricultural and industrial practices.

There are, however, certain measures urgently needed at present in order to lessen the speculative hazards connected with the economic development of peat resources in this country. The issue can best be solved by a careful scrutiny of some of the effects of the three varying and interfering major factors already mentioned.

The need for taking measures with respect to the necessary selection of peat lands for essential purposes is now generally conceded. Some of the differences between areas of peat, notably in the number, character, and profile position of the layers occurring in them, have been reported in several earlier publications (*13*). Plate 1 illustrates graphically a few of the more common type profiles. It is well to note that in the selection of peat lands for different uses two primary group distinctions should be kept in mind. Areas in the first group of peat lands consist predominantly either of sedimentary, of fibrous, or of woody layers of peat; the units of the second group represent different forms of combinations from these chief layers.

Areas of peat land with a profile showing the same composition of sedimentary peat materials throughout, as in cross section 1 of Plate 1, were formed in deep water. The areas undoubtedly represent the precipitation of organic material which previously floated or was suspended in the water. Together with mineral matter the fine-textured plant and animal remains settled as a dark-brown to blackish plastic peat material more or less gelatinous. It contains occasionally an admixture of less disintegrated fibrous or woody components which tend to give an open texture to the layer. The presence of large quantities of diatoms and sponge spicules may cause a burning and itching sensation in men and animals when this type of peat layer is plowed and cultivated. The sharp-pointed, siliceous material has a polishing and abrading effect on tools and implements. Peat lands of the sedimentary group are water-logged, often having excessive slopes and unfavorable adjacent topography. They lack firmness and stability under loads, increase the expense of drainage, and so decrease the profit of operation. Areas of a depth greater than 5 feet are relatively nonagricultural land; they may be set aside as reserves, for water-storage basins, or for wild life. Shallow deposits and those with a more favorable combination of layers, indicated, for example, by cross sections 1–2–1 and 2–1 in Plate 1, might serve as wild hay or as wiregrass marshes. If they can be drained moderately and furnish merchantable timber, as illustrated by profiles 1–3 and 1–2–3 of Plate 1, the growth of forest trees may possibly be more remunerative. It is of the greatest importance to retain the forests already on peat land for natural reproduction and gradually to clear away the poor growth by successive thinnings or improvement cuttings.

Peat lands with a cross section as at 2 in Plate 1 consist of brown or yellow-brown, raw, coarsely fibrous to felty peat material, only slightly disintegrated and more or less acid. Areas of this kind were developed under marshy conditions; the level of the ground water became elevated with the accumulation of plant remains or fluctuated moderately during wet and dry periods. This type of peat land can withstand considerable pressure where conditions require a cover of sand for cranberry growing or a roadbed for highway traffic. To be profitable, the areas of uniformly loose, fibrous composition demand deep fall plowing, freezing, and moderate drainage with a well-controlled water level. The resistance of the peat material to bacterial decomposition may give rise to an unfavorable action on plant growth for a long period of time. For that reason seeding and artificial planting of seedlings should not begin too soon following drainage; it should be delayed one to two years until the surface layer has begun to decompose and the peat soil has reached the tilth or ripened stage.

The differing fertility in this type of peat land may be due also to the mineral substratum or to other little-known factors confined to the area. Partly disintegrated and more carbonized, dark-colored phases of these type units, as well as areas with the cross sections 2–1–2, 1–3–2, and 3–1–2 in Plate 1, are preferred for the growth of the principal root and forage-producing crops, for temporary pasture, and in some cases for small grains. Regardless of the special purpose of the peat area, however, the fact should not be lost sight of that the rate and nature of the decomposition process depend for their continuation in large part upon the character of the peat material below the surface. It is of great economic importance, therefore, to select profiles which contain a large proportion of the nonfibrous fraction of organic matter in every layer of peat. Areas of coarsely fibrous types of peat, which decompose but slowly and by the action of a very limited number of microorganisms, are better suited for the preparation of shredded stable litter and composts (*10*).

One of the most important cultural operations necessary on units of peat land represented by profiles 2, 2–1–2, 3–1–2, and 2–3–2 in Plate 1 is the frequent use of heavy rollers to compact the soil. Implements such as plows, macerators, and tractors require sufficient wheel surface to carry their own weight on the soft, spongy ground. Applications of the liquid portion of barnyard manure are necessary from time to time to hasten a favorable decomposition of the fibrous portion of organic matter and an accumulation of available nitrogen through the activity of bacteria which fix atmospheric nitrogen. By tillage, such peat land may be made sufficiently productive later to justify intensive cropping.

Areas of woody peat land are illustrated in Plate 6, *A*, and by the profiles 3, 2–3, and 2–1–3 in Plate 1. A layer of woody material represents moderately disintegrated, dark-brown plant remains from swamp forests, more or less fragmented and neither strongly acid nor alkaline. The water level during the time of formation was sufficiently below the surface to favor a fair degree of decomposition by fungi and bacteria. Woody peat areas require more expense and labor in clearing and tillage, but they are usually peat lands of good productive power. Brush may be cleared at comparatively low cost by means of tractors equipped with wide wheels. A crop of corn or pasture of clover and tame grasses may be obtained without incurring the expense of removing the roots and logs. In general, shallow cultivation gives more satisfactory results than deep cultivation. Stable manure is not profitably employed upon this type of peat land, except for occasional light applications. Areas with cross sections such as are shown in profiles 1–2–3, 1–3–2, and 2–3–1 in Plate 1 are preferred for truck growing and market gardening, but the slower decomposition of coarsely fibrous or woody layers may yield material less readily available for the nutrition of crops and microorganisms. The whole process of transformation of the organic material may become changed for a time and injure the crops. With careful selection of the area, a natural wood lot may be conserved after drainage; this will supply the needs for rough timber, poles, fence posts, and fuel.

The separation and selection of peat lands based on the character of their respective profile sections will make practices consistent for different conditions and material. The structural framework, when properly analyzed, serves a very concrete purpose. It brings out the conditions under which excavating, draining, fertilizing, and preparing a seed bed should take place, and it indicates the cropping system which the individual areas of peat can best maintain. The method herein proposed for distinguishing between type units may prove helpful also in designing and constructing road or pile foundations and similar work where different profile features indicate a wide range of the bearing capacity of peat layers under concentrated loads. Figure 4 is instructive in showing the depth of penetration of a load and the compression and change in position of layers resulting from an over-

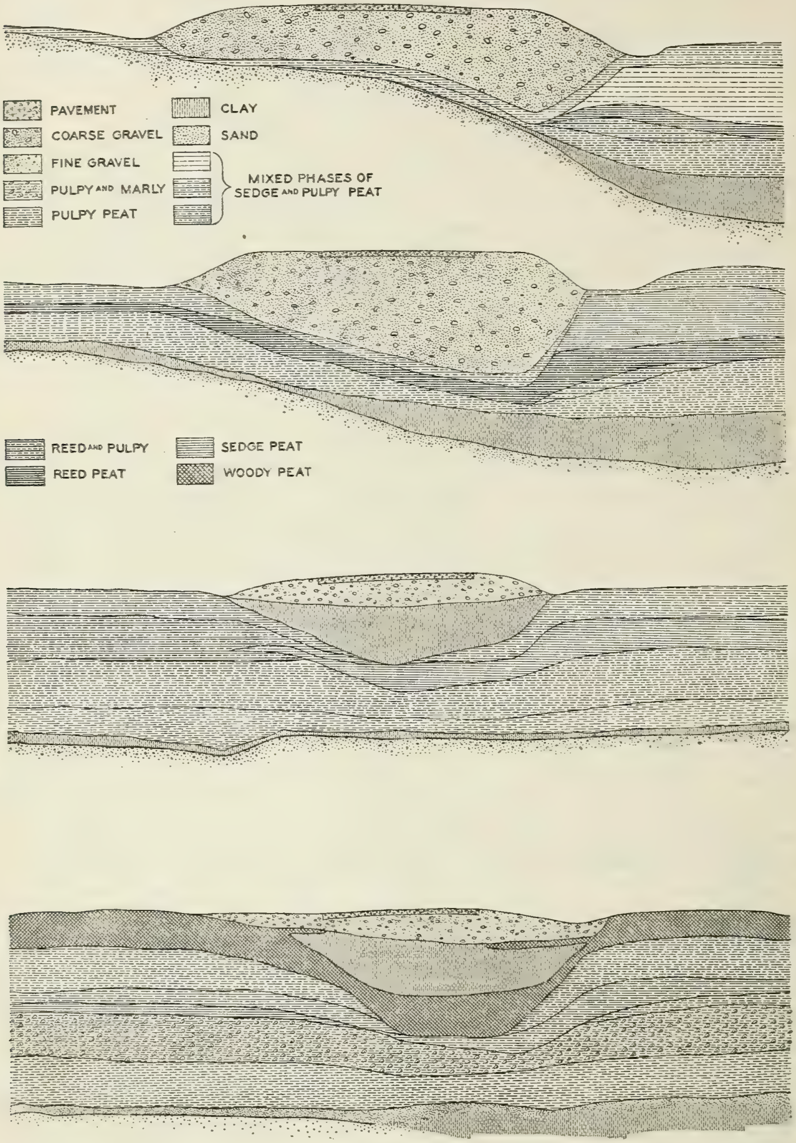


FIG. 4.—Displacement of peat layers under heavy road beds. Compare with Plate 7. (Courtesy of Michigan State Highway Department)

burden of fill used in the construction of highways. The areas under pressure yield gradually by plastic flow and may cause the sinking of a roadbed, as well as a lateral expansion and upheaval of adjacent peat layers. Engineering literature contains hardly a single description of the compressive strength of layers for different types of peat areas or a description of peat materials and their mechanical properties that would enable one to identify them with those from other locations. It would greatly benefit highway research if field investigations on this vital problem could be supplemented by laboratory tests, because the relation which exists between the strength in tension and compression of different types of peat and the bearing capacity of the same material at critical moisture contents is not yet known.

The stratigraphic classification of peat lands is of advantage also in determining what proportion of the peat-land resources may be devoted particularly to the development of improved varieties in crops or planned with respect to the better combination of crops, including shrubs and forest trees (*5, 20*). There is no reason why carefully selected regional areas of peat land should not produce cereals, seeds, grasses, clovers, sugar beets, and textile plants as well as truck crops or pasture for beef cattle and wool-growing sheep. In many instances, reforestation of certain types of peat land could be practiced much more extensively than has been done in the past, and industries utilizing peat materials could make marked contribution toward the production of stable litter and composts. Furthermore, knowledge of the structural framework will aid in developing the proper organizations among communities, especially of a cooperative character, for growing crops on a large scale or for advancing the specialization in farming and industry that may be desirable on complex types of peat land.

THE WATER TABLE AND ITS EFFECTS

Water is the outstanding physical condition affecting the origin of different peat materials and the formation of the profile structure of different types of peat land. The predominating surface vegetation generally indicates the effect of water content rather than the character of the peat soil. The thickness, number, and quality of sedimentary layers of peat definitely show correlation with high standing-water levels, while the accumulations of woody or fibrous peat layers correspond to a diminishing or fluctuating supply of moisture. When a wooded or marshy peat-land area is resubmerged or held in a wet condition for an indefinite period it reverts to the formation of a sedimentary layer of peat.

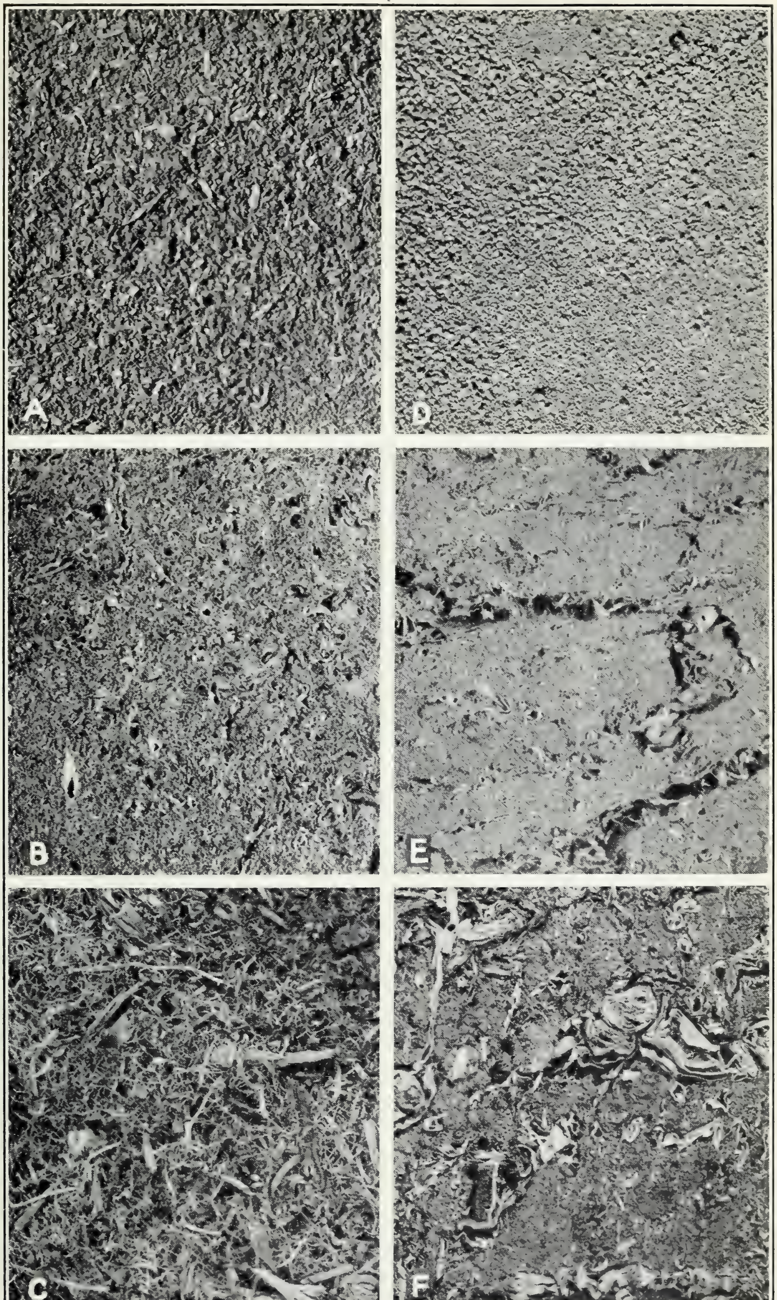
An insufficient knowledge of the effects of the water table has been, apparently, in most cases the reason why many farmers, manufacturers of peat products, and even drainage and highway engineers have met with frequent difficulties. Differences in the structural framework of peat lands have an important bearing upon estimating the drainage capacity of an area. They show very definitely, too, the respective need for a system to irrigate with free water or to control the mode of supply of soil moisture. How stratigraphic features may affect and in turn become affected by drainage or irrigation has not yet been given due attention.

An examination of profiles 2–1–2, 2–1–3, or 3–1–3 in Plate 1 will help to explain why sedimentary layers of peat may become displaced or protrude into drainage channels. On account of the pressure of heavy loads, such as a sand cover, a highway roadbed, or a dense stand of growing timber, the sedimentary material below yields gradually by plastic flow. In some cases this may lead to rapid subsidence, shallowing of ditches, damage to roads, or disalignment of tiles, and so increase the cost of maintenance. Subsidence of the surface layers, or their overburden, is certain to follow in areas which contain water pockets in or between layers of peat. The swamp forest shown in Plate 7, *A*, was submerged for a time, because of the sinking of the surface layer of peat. The underlying saturated layer of sedimentary material could not support the pressure of the increasing density in the stand of timber. The surface layer emerged after the trees had died.

The roadbed in Plate 7, *B*, sank into water pockets which occur between the surface layers of moss and sedge peat and the underlying water-logged layer of sedimentary peat. It has been further found that the displacement and upheaval of beds of peat along the sides of a sinking highway is not an uncommon experience. An instance of this kind is shown in Plate 7, *C*. In areas with the profiles exemplified by 1–2, 1–3, or 1–2–3 in Plate 1 a saturated basal layer of sedimentary peat, resting frequently on a water-logged mineral substratum, has no sustaining or cohesive power to support additional loads. But when the layer is dense and closely compressed and the water content reaches a critical stage at which the material becomes plastic, the weight of any overburden causes lateral expansion and consequently a more or less gradual lifting up of adjacent parts of the overlying layers. On the other hand, a surface layer of sedimentary peat, such as is shown in profiles 2–1, 1–2–1, 2–3–1, and 3–2–1, hardens under conditions of excessive drainage; it may become so firm and unyielding as to be practically useless for agricultural and other purposes. In addition, the downward percolation of surface waters is prevented, and the level of the ground water may fall to a depth sufficient to cause extensive damage from drought.

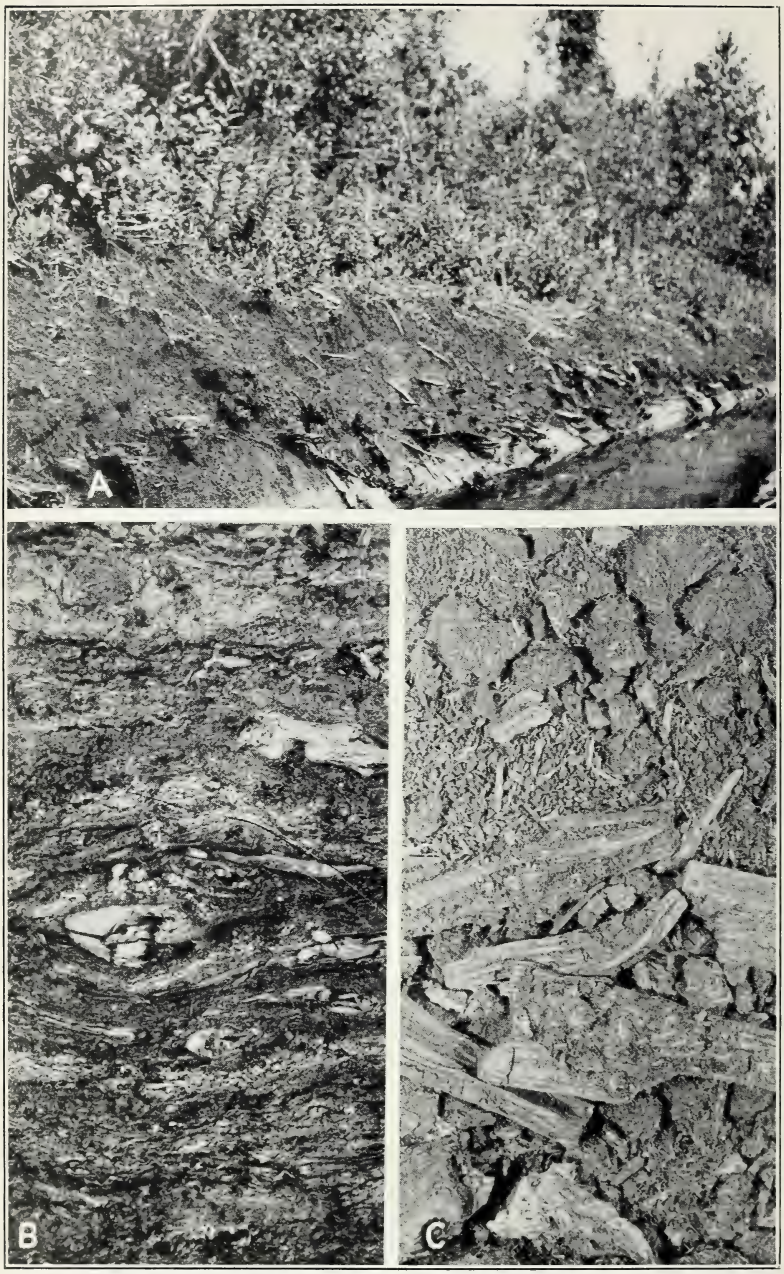
It is unnecessary to point out the great importance which attaches to irrigation for peat land having profiles of these types. Irrigated cultivation should be practiced not only during times of the growing season but upon all well-decayed surface peat soils. In fact, irrigation may be looked upon increasingly as the principal mode of water supply in the future adaptation of peat lands to crops. Maintaining an even, constant moisture condition would result in a slower shrinkage and more favorable decomposition; it would probably decrease to a minimum the rate of settling of an overburden, such as a cover of sand or road material. However, where the outlets are inadequate, it would be advisable to dike off the area and install a pumping system. But peat lands of the profile series beginning with 1 in Plate 1, which are of a relatively great depth and usually lack a natural outlet or fall, are difficult and expensive to drain. Investigations by the United States Department of Agriculture, indicate that subsidence immediately begins and continues at a fairly rapid rate until equilibrium is reached at or near the water level in the drained and cultivated area of peat. If cultivation is to be continued it becomes necessary to provide deeper drainage and the same cycle of subsidence is repeated. It deserves strong emphasis that areas of this type of peat land are better suited as reserves.

Fibrous peat lands of the profile series beginning with 2 in Plate 1 do not require to be drained to any great depth. They can be made



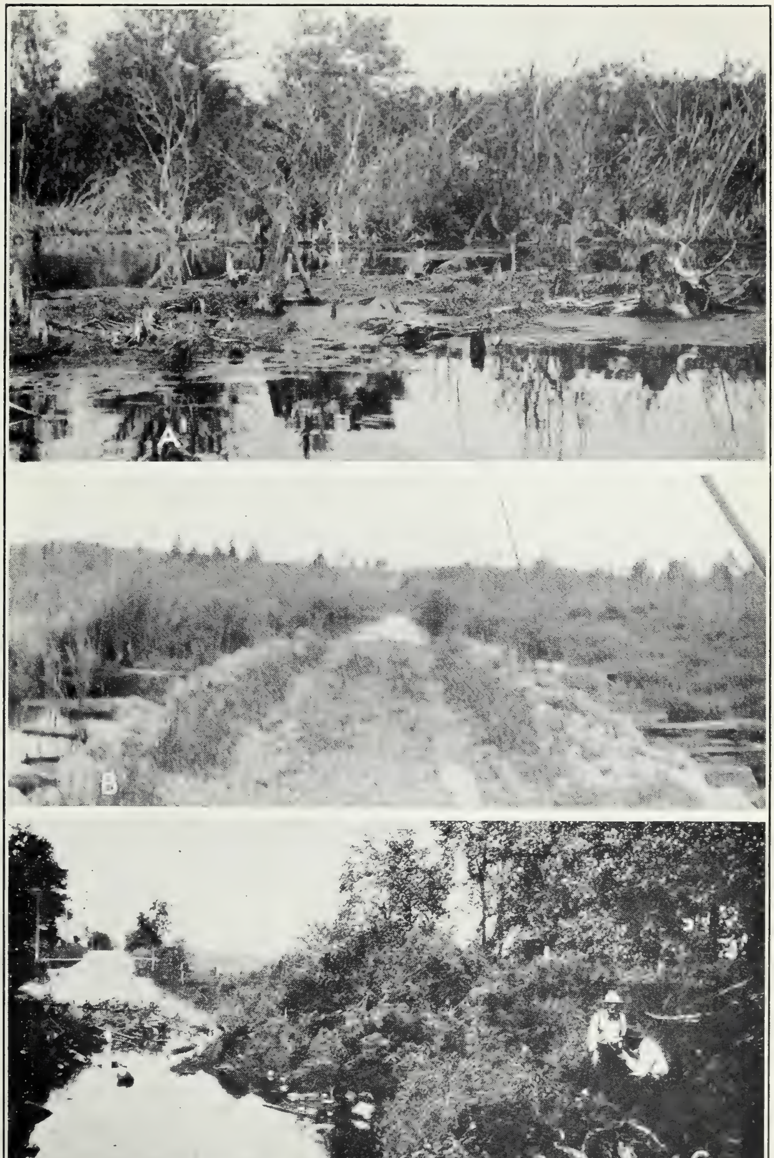
VARIETIES OF SEDGE AND REED PEAT

A, Sedge muck; *B*, radicellate sedge peat; *C*, coarsely fibrous sedge peat; *D*, reed muck; *E*, partly fibrous reed peat; *F*, coarsely fibrous reed peat. (All natural size from air-dry samples)



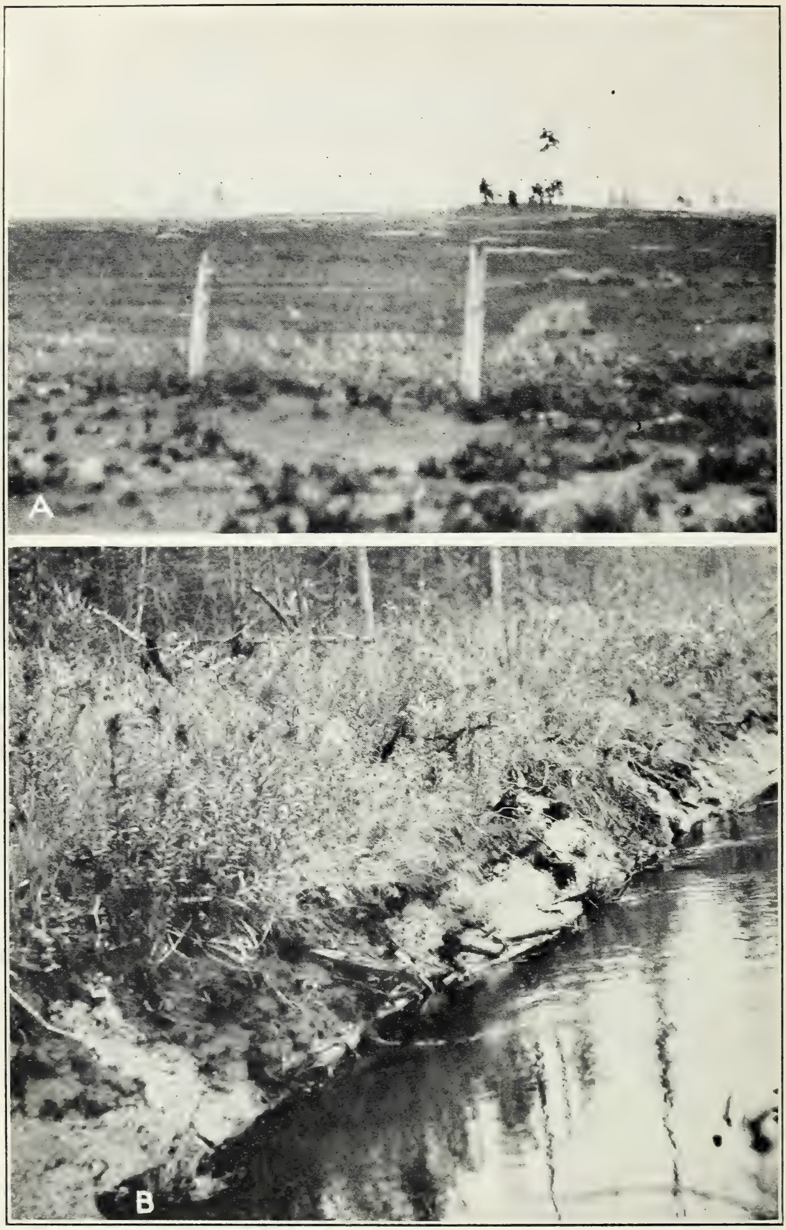
VARIETIES OF WOODY PEAT

A, Profile section of an area of woody peat; *B*, laminated woody peat from shrubs; *C*, partly decomposed woody peat from a swamp forest. (*B* and *C* natural size from air-dry samples)



SUBSIDENCE OF FORESTS AND HIGHWAYS ON PEAT LAND WITH AN UNSTABLE STRUCTURAL FRAMEWORK

A, Swamp forest which emerged after the trees had died; *B*, roadbed sinking into water pockets (photographed by H. R. Sayre); *C*, upheaved layers of peat along a sinking highway (photographed by W. E. Tharp)



INJURY TO PEAT LANDS CAUSED BY AN EXCESS OF IRON SALTS IN GROUND WATERS

A, Mounds of iron concretions on burned-over peat land; *B*, drainage waters precipitating iron in ditches (photographed by V. R. Burton) profitable through the organization of main waterways for irrigation or temporary flooding. Close spacing of relatively shallow ditches or of box drains and tile is believed to be preferable, since it results in a more rapid run-off and more uniform lowering of the water table between the ditches. Variation in water level is less and the rate of flow of water is generally better in the loose than in the more compact and finer textured layers of peat. In the carbonized and disintegrated phases of fibrous peat land a wider spacing of deeper ditches is usually followed. Layers of this stage of disintegration tend, however, to retain the moisture, retard the movement of water through the soil to the outlet, and consequently lead to an uneven shrinkage and to irregularly sloping surfaces when the distance between drains is too great. As many laterals as possible should drain into each main ditch. A system of moderately deep ditches or drains with close spacing appears, therefore, to be more desirable even in the case of well-decayed phases of fibrous peat land. Under these conditions it would seem that the spacing of box or tile drains should not exceed 200 to 300 feet and the depth of the drained horizon should not be greater than 2½ to 3 feet, depending upon the crops to be grown and the amount of rainfall.

Areas of peat land which have very coarse fibrous layers at different ranges of depth below the surface eventually may cause more or less settlement upon subsequent decomposition. There are instances also where swelling and upward expansion of layers of spongy, fibrous peat have been observed during wet seasons following a prolonged dry period. Units of peat land containing these types of material may show curved surfaces, bulging sufficiently to cause crops to suffer from lack of moisture. A system of water-level control provides the most satisfactory method to avoid this difficulty.

The chief damage from drainage to woody peat lands is limited to crumbling. This may gradually obstruct or block open ditches and finally lead to a renewed rise of the water table and to water-logged conditions. Where the quantity of water to be drained is relatively large, drains and ditches in woody peat erode more easily than the ditches in fibrous-peat land. On that account the ditches should be given sloping walls in the more decayed and also in the mixed phases of peat layers.

So important is the control of the water relation to peat-land utilization and so definitely useful is it to crop production that the closest attention and cooperation in this matter is well deserved. The experience of drainage districts and the publications of experiment stations [3] clearly indicate that a successful solution of the drainage of peat lands means much to the prosperity of the States concerned. Many early settlers have failed because the drainage was either excessive or not complete and because supplementary drains or dams and checks for the control of the water level were not put in to maintain favorable moisture conditions for tillage and manurial treatments. Moreover, except in certain areas it has been exceedingly difficult to bring about a control of the water level.

The significance of a well-balanced water supply throughout a crop season becomes clearer when it is recalled that the specific water

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[3] The following serial numbers refer to publications on drainage in "Literature cited," at the end o this bulletin: *2, 7, 16, 18, 21, 22, 25.*

requirements of different crops are not the same. Meadows require a water level near the surface; pastures are more profitable with a lower water table; cultivated farm and garden crops usually need a much greater depth to ground water. The position of the water level influences also to a marked degree the penetration of heat and the effect of frost. The fact is well known that crops on peat lands are more seriously damaged by frost than those on mineral soils. Although the frost hazard can be reduced by using fertilizers, by a thin surface coating of clay, sand, or loam, and by more hardy crops in the rotation, it can be further lessened by better control of the soil moisture. If the water table is properly lowered, peat land can be compacted and cultivated earlier in the spring. Moreover, deep drainage during winter favors a deeper aeration and disintegration. Unaerated, water-soaked layers, on the other hand, show a tendency toward leaching and corrosion. The extent of the injurious effects is often difficult to determine, particularly the corrosion of tile drains and cement foundations. In this connection, it should be kept in mind that the moisture content present in the profile section does not depend altogether upon the distance to the ground-water level but in part upon the character of the peat layers and the stage of disintegration. Hence methods of aeration and cultivation should be adapted to the structural profile features, in order to alter the respective water-holding capacity of the different types of peat land.

EFFECTS OF THE MINERAL SUBSTRATUM

The widely differing profile features of peat lands point to the fact that during the formation of a peat deposit the plant tissues and other organic remains in layers of peat are not greatly altered by chemical or bacterial action. It appears fairly clear, also, that the character and the number of different superimposed layers of peat overlying a land area are not determined by the nature of the mineral subsoil or its topography. The most tangible and readily recognized chemical change in undrained peat lands is seen in the marked deficiency of certain fertilizer constituents, in the progressive loss of oxygen from the plant tissues forming layers of peat, and in the reducing action of the water in various peat materials (*6, p. 372*).

The conditions are quite different, however, when an area of peat has been drained, the surface layers are cleared and aerated, and decomposition of the organic matter sets in. Generally speaking, the solubility of mineral soils underneath peat areas is greater than that of the adjoining cropped and leached upland soils. The proportion in which the various mineral constituents are given up and accumulate in the rooting zone of crops is therefore highly important. Where these salts are dissolved in the soil moisture, the concentration of the solution may become excessively great in the course of time (pl. 2, *B* and *C*). The spots formed may prevent seeds from absorbing enough moisture to germinate, and they may injure the roots of plants growing at some distance from the place supplying the salts. It appears that the more disintegrated phases and finer textured types of peat are likely to show greater injury from dissolved salts and the adsorptive effects of organic colloids than the loose, fibrous layers of peat. Too much can not be said, therefore, about the desirability of studying carefully the mineral substratum as a limiting factor.

Very few systematic observations of the influence of different mineral salts, including lime and fertilizers, upon cultivated peat lands have been made thus far. It is recognized to be a great drawback to the work that the analyses made are not comparable, because of the employment of widely different peat areas and methods of work. On this account opinions have been at considerable variance as to the effect of mineral salts in promoting the decomposition of peat materials, in accelerating the activity of beneficial microorganisms, or in modifying the availability of salts and organic compounds for the growth of crops. There is also the problem of alkali salts on certain peat lands, a solution of which can be reached, here as in other questions, only when a uniform method of analysis is employed.

The outstanding feature of fertilizer analyses, reported by State experiment stations and other agencies,[4] is the deficiency of potash and phosphates. Accordingly, the continued use of potash salts for crops such as potatoes, onions, or sugar beets, which show a response to this fertilizer, has become profitable on nearly all types of peat lands. Phosphates have the advantage that they stimulate the activities of certain microorganisms; thereby they lead to a more thorough utilization of the organic material of fibrous-peat areas and to the formation of larger quantities of available plant-food constituents.

Nitrogen, assimilable by crops, is most often deficient in coarsely fibrous peat layers. For this reason, frequent applications of soluble nitrate fertilizers are needed, in order to prevent injury to growing plants and to hasten the decomposition of the layers. The use of artificially prepared bacterial culture does not, however, assure a natural and normal inoculation of this type of peat land or of the seeds of nonleguminous plants. The best natural method for obtaining available nitrogen depends on the type of peat material, its proper preparation, and on the seasonal conditions. Moderately fibrous layers of peat, judiciously provided with lime, fertilizers, and an abundance of air and moisture, favor the fixation of free atmospheric nitrogen by bacteria. Suitable crop rotations are another means to this end. The liberal application of nitrogenous fertilizers is economically remunerative only with crops of high commercial value, grown under intensive cultivation. Before satisfactory results are obtained, it is often necessary to apply excessive and probably unprofitable quantities of potash and phosphate to restore a balance for plant growth. The conditions which favor losses of nitrogen are not well known, but fine-textured heavy peat soils show greater depletion of nitrogen than loose, light layers of peat. On the whole, a practical trial in the field from time to time affords the best method of determining the fertilizer requirements of individual peat areas or crops. It is a well-known fact that the fertilizer needs of peat soil can not be determined from their chemical analysis.

Acidity in peat lands is of varying nature, the reaction being more or less influenced by the profile structure of the area and the differences in soluble salts. The high content of carbonaceous substances but slightly broken down in peat lands of the profile series with digit 2 in Plate 1 constitutes a reserve of potential acidity which is impos-

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[4] The following serial numbers refer to publications on fertilizer analyses in "Literature citied," at the nd of this bulletin: *1, 2, 3, 4, 17, 19, 20, 23, 24.*

sible of measurement. The actual presence of organic acid is, however, considered to be less important than the injury due to mineral acids and to lime deficiency. This condition may be remedied by the careful use of finely ground lime. Determinations of acidity and basicity have been included in systematic field work, partly because convenient and fairly accurate methods are available for this purpose. The results, however, are still inconclusive, because the different methods of determination give different indices of acidity. The Azotobacter test might be decidedly preferable as regards the lime requirement and the quantity of available salts, such as phosphates, needed to render a layer of peat productive. Further work on this subject is much to be desired.

Not only do reclaimed peat lands vary widely among themselves in the fertilizer treatment required to make them profitable but also the chemical composition of layers of peat under cultivation changes continually. The methods of investigation are not yet sufficiently delicate to follow these changes from peat to muck and humus. Chemical and bacteriological tests should therefore be made over a long period of years on peat lands with a specific profile.

Relative to the influence of the mineral substratum, the following conditions should be taken into account in the selection of peat lands for different uses. It is difficult to obtain satisfactory results on peat lands with unfavorable topography of the adjacent land, steep slopes, lack of outlet or fall, stony, gravelly, and quicksand subsoils, or hardpan underlying relatively shallow depths of peat. Excessive quantities of soluble salts, sulphur, and iron contaminations give rise to spotty areas, and even peat lands of considerable depth have only a limited value under such conditions. Deep drainage and evaporation during periods of hot, dry weather must be fully reckoned with as the influences that bring salts from the mineral substratum to the surface. On the other hand, cool rainy seasons prevent a high concentration of soluble salts, both by stopping excessive evaporation and by leaching and distributing the mineral salts.

Typical injury caused by iron salts is shown in Plate 8. The burned-over area of peat land (pl. 8, *A*) contains solid mounds of iron concretions in a locality where the ground waters and springs are ferruginous. Plate 8, *B*, gives a closer view of the newly excavated ditch, the drainage waters of which contain large quantities of iron in solution. Upon exposure to the air the iron becomes insoluble and precipitates. The cost of necessary labor and fertilizers and of transporting and marketing make unprofitable the utilization of peat lands with injurious subsoils. They should be recommended for suspension or exclusion until a thorough and systematic search for the presence of harmful substances in the mineral substratum has been made.

How extensively iron sulphide in the form of marcasite occurs in the underlying mineral soil of peat lands is not known. Nowhere, however, does it threaten any injury except after drainage. Because of oxidation by the air, marcasite forms ferrous sulphate and sulphuric acid, both of which are soluble in water and injurious to crops. In contact with calcareous waters or any form of lime these two substances are changed into calcium sulphate (pl. 3, *C*). Unproductiveness from this cause will not disappear until all the sulphide has been neutralized by lime and any remaining pyrite has oxidized and leached out. Sedge marshes with unfavorable mineral subsoils should be left as wiregrass meadows or drained moderately to permit the cutting of wild hay. If areas of peat land with a substratum of this nature are naturally wooded they should be kept, preferably as woodlot reserves. Areas of peat with excessive quantities of shell and Chara marl may become undesirable, on account of the deleterious effect of an excess of alkalinity on plant growth.

Peat lands which accumulated over till, clay, or sandy-loam subsoils constitute, as a rule, the better grade for utilization. Neutral to slightly alkaline peat areas appear to fix larger quantities of fertilizers than the acid peat soils of the same type, but the degree of fixation and the compounds formed need further investigation. The presence as well as the character of thin layers of silt or marl and their location in the profile should not be ignored. In time they react favorably upon the surface layers, which are generally more or less acid, and they likewise influence the quality of crops.

If the industrial use of a deep peat area is contemplated, only such deposits should be excavated of which the mineral substratum is in a condition suitable for future crop requirements or for the production of fishponds and aquatic crops. The latter is a field of work which so far has been little investigated.

SUMMARY

The problem of selecting peat lands for economic uses, like other problems of land utilization, demands reasonable forethought and planning. The chief hazards in the agriculture and industry of peat lands may be grouped into three classes: (1) Differences between peat lands in their distinctive structural framework; (2) lack of a proper method of controlling the supply of soil moisture; (3) the accumulation in the root zone of crops of excessive quantities of soluble salts from the mineral subsoil. These three difficulties may occur together, or any one of them may cause disastrous results. A clear understanding of the nature and effects of these three classes of trouble that may develop on peat lands makes it possible to have a better basis for operations and to anticipate financial and other difficulties before they have progressed to the point of serious injury to the community.

There can be no doubt that a definite attempt to find and locate peat land with the most favorable structural framework and field conditions would benefit the regional development of peat-land utilization. It would reduce economic waste and encourage the conservation of peat areas that are important and feasible for water-storage purposes, for reforestation, and for wild-life reserves. Even a casual survey of noteworthy attempts made by several of the States collaborating with this department brings out the fact that the groundwork is already well laid for selecting desirable peat lands upon the basis of their stratigraphic framework. With proper attention to a related and continuously controlled water supply and like attention to the possible danger of an excess of active soluble salts from the mineral substratum, the prospect for effective advancement seems assured. The establishment of a well-considered program of selection will give to peat-land utilization the stability and permanence which it has not heretofore possessed.

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