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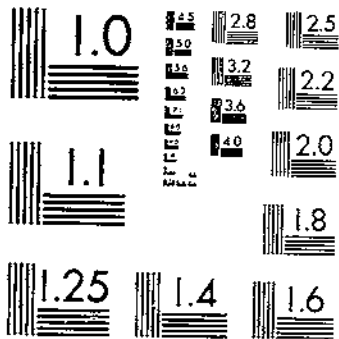
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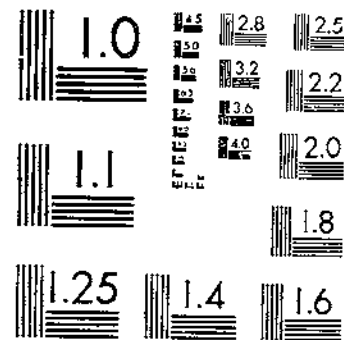
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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF CERTAIN AMERICAN PEAT PROFILES

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INTRODUCTION

The areas of peat land in the United States, of which approximately 100,000,000 acres are estimated to be of potential economic importance to industry or agriculture, have not been classified on a basis of physical and chemical characteristics as have the normal mineral soils, and only fragmentary data are at present available concerning these properties.

Attempts have been made to distinguish between different types according to botanical origin of the peat material, according to certain chemical analyses, and according to response to liming and fertilization. These very different characteristics have proved more or less satisfactory for segregating different peats in restricted localities, but they do not appear to be entirely suitable for a general classification or knowledge of important physical and chemical properties.

A survey of the literature on peat reveals an enormous mass of data dealing with a wide variety of phases of the subject, most of which, however, pertain to elementary and proximate analyses and thermal values (33),¹ inorganic constituents, reaction, and less frequently such fractions as the ether or alcohol soluble material (17, 18) of peat found in various deposits. A few investigators have identified certain definite complexes (26, 14, 30, 31) in the organic matter, and others have investigated the nature of the so-called humic acids (15, 20, 21), which has given rise to confusion.

¹ Italic numbers in parentheses refer to Literature Cited, p. 24.

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Previous investigations of the physical and chemical nature of the organic matter of peat have in reality yielded little information. Furthermore, future progress along this line of research must of necessity be slow on account of the great complexity of such a mass of partly decayed vegetable matter as is found in peat. Certain advances, however, have recently been made by Dachnowski (3), Odén and Lindberg (22), Waksman and Stevens (38), and Thiessen and Johnson (34). These investigations represent attempts made for the most part to adapt methods used in the analysis of plant materials to the organic analysis of peat.

Considerable is known concerning the botanical origin and composition of many peat deposits, but these facts alone can provide only a limited knowledge of the physical and chemical characteristics of peat profiles, since processes of decay have greatly altered the original properties of the plant material.

An excellent historical résumé of the chemistry of peat, which clearly indicates the necessity for extensive and systematic research, is given by Waksman (36, 38).

In general it is difficult to make comparisons between the various areas of peat because of the lack of uniformity in the methods of examination employed and because the available data are incomplete. Analyses have been made in most cases on samples from a single deposit or on one or more strata of a deposit.

It seemed worth while, therefore, to undertake a preliminary investigation of a fundamental character dealing with the general properties of various peats, using uniform methods of examination throughout. The object of the present study has been to determine the physical and chemical characteristics not only of the surface layers but also of the complete profiles, where such were obtained, with the double purpose of ascertaining the range of properties between several different deposits and also how these properties vary with depth and therefore, at least roughly, with the age of the material. Such a survey was expected to serve as a contribution to the knowledge of fundamental similarities and differences between various peat areas, at present distinguished for the most part by the predominating type of vegetation or geographical location, and also to serve as a basis for more extensive investigations along those lines having a more practical application to agriculture.

DESCRIPTION OF SAMPLES

The samples used in the present study were collected by A. P. Dachnowski-Stokes of this bureau and are from areas in the States of Maine, North Carolina, Florida, and Washington. These areas have been described in considerable detail in recent publications (5, 6, 7, 8). The samples collected are briefly described as follows:

Orono, Me.: Profile section from approximately 2½ miles southwest of town (5).

- (1) 3 to 6 inches: Light yellow-brown fibrous and spongy sphagnum peat, poorly decomposed.
- (2) 6 to 9 inches: Slightly darker sphagnum peat, poorly decomposed.
- (3) 9 to 12 inches: Light-brown sphagnum peat, poorly decomposed.
- (4) 2 to 3 feet: Similar in appearance to layer above.
- (5) 3 to 4 feet: Brown sphagnum peat, poorly decomposed.
- (6) 10 to 11 feet: Dark-brown woody peat, partly decomposed.

Cherryfield, Me.: Profile section from about 18 miles northwest of town (5).

- (1) 2 to 4 inches: Light-brown spongy sphagnum peat, poorly decomposed.
- (2) 5 to 8 inches: Light reddish-brown sphagnum peat, slightly decomposed.
- (3) 8 to 12 inches: Similar in color, somewhat firmer, partly decomposed.
- (4) 12 to 18 inches: Dark-brown sphagnum peat with traces of coarse and fine woody particles, partly decomposed.
- (5) The remainder of this profile was not obtained. The total depth of the deposit is about 22 feet.

Beaufort, N. C.: Profile section from vicinity of Buck Head Lodge (8).

- (1) 0 to 3 inches: Reddish-brown to dark-brown largely decomposed woody debris from heath shrubs embedded in a dense network of rootlets.
- (2) 3 to 6 inches: Reddish-brown to dark-brown woody material largely decomposed, containing well-preserved roots and underground stems of heath shrubs.
- (3) 6 to 9 inches: Similar to layer above.
- (4) 9 to 12 inches: Same but darker brown, finely divided.
- (5) 12 to 15 inches: Dark-brown to black, with sticky, amorphous sedimentary admixture.
- (6) 15 to 18 inches: Similar to layer above.
- (7) 24 to 30 inches: Yellowish-brown finely divided sedimentary peat.
- (8) 37 to 42 inches: Yellow-brown woody, partly decomposed white-cedar forest peat.

Belle Glade, Fla.: Profile section from the Brown plantation about 15 miles southeast of Lake Okeechobee on the Hillsborough Canal (6).

- (1) 0 to 4 inches: Blackish-brown partly carbonized, granular to powdery, partly decomposed, dry saw-grass peat.
- (2) 4 to 6 inches: Dark-brown partly decomposed saw-grass peat.
- (3) 32 inches: Black fairly compact sedimentary material with embedded brown fibrous saw-grass plant remains.
- (4) 49 inches: Dark-brown fibrous saw-grass peat with small amounts of black sedimentary admixture.
- (5) 63 inches: Similar in appearance, partly decomposed saw-grass peat with sedimentary admixture.
- (6) 94 to 96 inches: Similar, partly decomposed saw-grass peat.

Miami Canal at Lake Okeechobee, Fla.: Profile section from vicinity of the Miami lock (6).

- (1) 15 to 30 inches: Black to gray-black amorphous, granular sedimentary (custard-apple) peat, largely decomposed.
- (2) 42 to 48 inches: Same but more coarsely lumpy and cloddy.
- (3) 62 to 68 inches: Dark-brown sedimentary material with large amount of brown fibrous roots embedded.
- (4) The remainder of the profile was not obtained. The top layer (0 to 15 inches) was contaminated through dredging operations near-by and was not sampled. The total depth of the deposit at this point is 15 feet.

Clewiston, Fla.: Profile section from approximately 5½ miles southwest of town (6).

- (1) 0 to 4 inches: Dark-brown to black fibrous felty saw-grass peat with some carbonized material.
- (2) 10 to 16 inches: Dark-brown fibrous saw-grass peat, partly decomposed.
- (3) 20 to 26 inches: Similar material but somewhat firmer and more decomposed.
- (4) 30 to 36 inches: Dark-brown to black partly fibrous peat with considerable white sand present.

Monroe, Wash.: Profile section from a main excavation southwest of town (7).

- (1) 0 to 6 inches: Light-brown coarsely granular to powdery woody sedge peat, poorly decomposed.
- (2) 10 to 16 inches: Brown herbaceous-sedge peat consisting largely of fibrous fragments, poorly decomposed.
- (3) 18 to 24 inches: Dark-brown tulle-sedge peat, partly decomposed.
- (4) The remainder of the profile was not obtained. The total depth of the deposit is about 4 feet.

EXPERIMENTAL METHODS

METHODS FOR DETERMINING PHYSICAL PROPERTIES

The volume weight was determined in the usual manner by weighing a core of known volume taken in the field and immediately sealed after sampling. A description of the sampler used is given by Dachnowski-Stokes (5).

The specific gravity of the peat in the saturated condition was determined on a portion of a sample saturated in exactly the same way as for the maximum water-holding capacity described below. Approximately 10 grams of the material was placed in a Hubbard-Carmick straight-walled picnometer having a wide mouth, which allows the introduction of the saturated peat without danger of squeezing out water. The stoppered picnometer was then quickly weighed, filled with water, and the specific gravity determined at 25° C. in the usual manner.

The absolute specific gravity of the dry peat was determined on a sample which had been dried in an oven for 48 hours at 105° C. Some difficulty was experienced in causing the material to take up water after placing a weighed portion in the picnometer. It was found best to partly fill with water and allow to stand for some time with frequent stirring, followed by boiling under vacuum. This treatment was sufficient for all cases, some samples requiring relatively more time and manipulation than others.

The apparent specific gravity of the dry peat was determined by filling the picnometer containing the weighed sample with sand instead of water. The sand used was fairly uniformly graded, most of it ranging in size from 0.25 to 1 millimeter, and was well mixed before use. The picnometer was filled with three layers, and each layer packed by gently tapping on a wooden block 25 times. After the picnometer was completely filled the excess sand was carefully scraped off even with the top, with a knife, the lid not being used. The calibration was previously made in the same manner, and the volume of the picnometer was determined by filling with water and covering the top with a small glass plate in order to occupy the same gross volume as that of the sand. The weight of this water allows the calculation of the apparent specific gravity of the sand. The weight of sand displaced by the sample is converted to volume which corresponds to the apparent volume of the sample, and from this its apparent specific gravity is readily calculated.

The determination is somewhat difficult and not entirely satisfactory, especially for the more fibrous peats. It is best to have the dry sample core-shaped, if possible, with a diameter slightly greater than half that of the picnometer and with a flat surface resting on

the bottom of the picnometer, otherwise it is difficult to fill with sand so that there will be no air pockets. After one determination has been made the result may be checked by emptying the picnometer and refilling as before. The accuracy in filling limits the weighing to one or two decimal places.

For the determination of the maximum moisture-holding capacity as well as for the determination of its specific gravity, it is necessary to have the peat in its natural moist condition, and consequently the sample jars must be tightly sealed in the field to prevent evaporation. If the peat is allowed to dry, or even partly dry, water will not again be absorbed to the same extent as before drying.

Moisture-equivalent boxes were used so that the moisture equivalent could be determined on the same portion without transfer of material. The peat was placed in each box to a depth of approximately 1 centimeter and allowed to stand in a shallow pan of water as in the case of the ordinary procedure for soils. After about two hours the boxes were removed and allowed to drain overnight supported on glass rods in a moist atmosphere under a bell jar. The samples were weighed after the boxes had been covered and the excess water adhering to the bottom carefully wiped off.

Immediately after the saturated samples were weighed, the moisture equivalent was determined at 1,000 times the force of gravity in the same manner as for ordinary soils. The boxes were again weighed, and the peat was then allowed to become air dry.

The maximum moisture-holding capacity and moisture equivalent determinations were repeated on the air-dry samples contained in the moisture-equivalent boxes. Longer time must, however, be allowed for saturation. About seven hours was usually found sufficient, the water being allowed to completely cover the sample. The layer of the air-dry peat is of course much thinner than the layer of peat in the original condition and takes up water readily in most cases.

After air-drying again, the samples were dried in the oven for 48 hours at 105° C. and all calculations based on the oven-dry weight.

The reaction of the peat was determined in the fresh condition by means of the hydrogen electrode. A proportion of about 1 part of peat to 5 parts of water seemed to give the best results.

METHODS OF CHEMICAL ANALYSIS

The methods used for the analysis of the organic material are essentially those described in detail by Waksman and Stevens (28). A few modifications and additions were made as follows:

Ether, alcohol, and water extractions were carried out on a 5-gram sample of the air-dry peat (2-millimeter mesh material) in the order named, the first two in a Soxhlet and the latter under a reflux condenser, 250 cubic centimeters of water being used. The ether and alcohol extractions were run for seven hours each and the water extraction for two hours, after which the processes were repeated for the same respective periods of time. Such a method of extraction by alternation of solvents is probably more efficient on a basis of quantity of material extracted than a method consisting of single extractions with the same solvents as described by Waksman. The extracts were evaporated and dried at 105° C. to constant weight and corrected for ash by ignition.

The residue from the second water extraction was dried and weighed, given a 2 per cent hydrochloric acid treatment, using 150 cubic centimeters of solution, and refluxed for five hours. The insoluble material was again dried and weighed to determine by difference the material which had gone into solution by the acid treatment. Hemicelluloses are hydrolyzed by dilute acid and converted into simple sugars. Cellulose remains unaffected and, according to Schorger (29), differs in constitution from a hemicellulose in that the latter polysaccharide may give various hexosans and pentosans on hydrolysis, whereas the former gives glucose only and requires a much stronger acid, such as 72 per cent sulphuric acid.

Ether and alcohol extractions were repeated in a Soxhlet for 14 hours each, after the dilute acid treatment, followed by another drying and weighing of the residue. These extractions are not included in Waksman's methods but were added for purposes of further information. The remaining material was then placed in a beaker and treated with 50 cubic centimeters of 72 per cent sulphuric acid in the cold for 18 hours, diluted to 800 cubic centimeters, gently boiled for two hours, and filtered. The residue was weighed and accounted for as "lignin-humus complexes" after deductions were made for ash and protein (nitrogen $\times 6.25$) content. The total material soluble by the sulphuric acid treatment was calculated by difference as in the case of the hydrochloric acid treatment. The strong acid was allowed to act in the cold for 18 hours, which is recommended by Schorger in the determination of lignin in wood as necessary for complete solution of cellulose, instead of only two hours as in Waksman's methods.

Nitrogen determinations were made on aliquot portions of the acid fractions and on the final lignin-humus residue. Portions of the hydrochloric and sulphuric acid extracts were also analyzed for reducing sugars, after neutralization with sodium hydroxide, using the official Munson and Walker method of the Association of Official Agricultural Chemists (1a), and results of each were calculated as hemicelluloses and celluloses, respectively, by multiplying the reducing-sugar content by the factor 0.9. It is not definitely known, however, whether or not the method of analysis for these components, whose presence is indicated by the formation of reducing sugars, is entirely adequate, but it is assumed to be sufficiently so for purposes of comparison.

The proximate fuel analyses were made by a method similar to the standard method used for coal. A crucible was filled about two-thirds full of 2-millimeter mesh material and weighed. A fairly constant volume was thus used instead of a constant weight which seemed impractical in the case of peat, because of the great variation in the volume of a given weight when dry. Heating was begun very cautiously with a low flame to avoid too rapid evolution of the volatile matter and consequent danger of loss of material. The gentle heating (below dull redness) was continued for several minutes until the greater part of the readily volatile matter had escaped. The full regulation flame was then applied for seven minutes, and the residue weighed and then ignited in a muffle furnace and heated to constant weight at dull-red heat. Calculations were made for

volatile matter, fixed carbon, and ash as in the proximate analysis of coal.

The elementary analysis for carbon and hydrogen was carried out in the ordinary electric combustion furnace. Approximately 0.2 gram of material was placed in a porcelain boat and slowly heated to the required temperature in a dry stream of oxygen. Products of combustion were oxidized by passage through a hot plug of asbestos wool, about 35 centimeters in length, as a catalyst. The water was absorbed in a Fleming absorption bulb containing calcium chloride and phosphorus pentoxide, and the carbon dioxide absorbed in a similar bulb containing soda-lime and phosphorus pentoxide. About an hour and a half was required for the complete combustion and sweeping out of the tube.

All nitrogen determinations were carried out according to the official Gunning-Hibbard modification of the Kjeldahl method except that in the case of total nitrogen determinations a few crystals of potassium permanganate were added to the digestion flask about an hour after the mixture had become colorless from the sulphuric acid digestion. This insured a complete oxidation of the more resistant peats.

For the analysis of the ash the peat was ignited in a muffle furnace at dull redness to avoid loss of alkalis until the ash became white or all evidence of carbon had disappeared. It was then ground to pass a 100-mesh sieve and bottled after coming to an approximate equilibrium moisture content with that of the air. It is best to make a separate moisture determination and calculate results of the analysis to the dry basis rather than attempt to weigh the dry ash directly for an analysis.

Standard procedures used in the division of soil chemistry and physics for the analysis of soils were employed. The constituents determined were: SiO_2 , Fe_2O_3 , Al_2O_3 , TiO_2 , P_2O_5 , CaO , MgO , SO_3 , Na_2O , K_2O , MnO , and CO_2 . A division of the silica was made according to its solubility in hydrochloric acid and sodium carbonate in an attempt to distinguish between true plant SiO_2 and sand. Five-tenths of a gram of ash was digested with 150 cubic centimeters of water and 10 cubic centimeters of hydrochloric acid on the steam bath for a time and filtered. The residue was treated with 5 per cent sodium carbonate and boiled for five minutes. The solution was filtered, and the two filtrates were combined, evaporated to dryness, and the silica was determined in the regular manner. This gives the soluble silica, and the insoluble silica or sand is determined by difference from the total silica in the ash.

RESULTS OF PHYSICAL TESTS

The results of the physical tests are given in Table 1. The volume-weight determinations are variable, and duplicates do not check very well. The values represent an average of two results for each sample but are probably of little significance, at least for comparative purposes, since they are greatly influenced by the water content of the deposit sampled.

TABLE 1.—Results of physical tests of samples of peat from various localities

Location of sample	Description of sample	Depth	Volume weight ¹	Apparent specific gravity		Absolute specific gravity (oven-dry)	Maximum moisture holding capacity		Moisture equivalent		Maximum shrinkage	Air-dry moisture	Reaction
				Saturated	Oven-dry		1	2	1	2			
		Inches	Grams				Per cent	Per cent			Per cent	Per cent	pH
Orono, Me.	Sphagnum peat	3-6	0.436	1.012	0.14	1.588	3,235	2,000	628	600	78	12.0	3.8
	do	6-9	.413	1.012	.11	1,590	3,115	2,210	619	588	71	10.8	3.9
	do	9-12	.424	1.016	.14	1,557	2,420	1,485	558	501	71	11.2	3.8
	do	21-36	.645	1.016	.06	1,501	2,640	1,620	562	504	38	11.0	4.0
	do	36-48	.587		.08	1,525	2,735	1,585	572	481		11.1	
Cherryfield, Me.	Woody peat	120-132	.770		.78	1,463	1,070	278	447	206		11.4	
	Sphagnum peat	2-1	.678	1.015		1,515	3,210	2,370	481	452		10.2	3.7
	do	5-8	.914	1.020		1,503	1,810	1,085	409	366		8.8	3.8
	do	8-12	1.082	1.017		1,473	1,600	858	422	343		9.0	3.65
	do	12-18	.090	1.023		1,388	1,475	366	492	274		9.8	3.65
Beaufort, N. C.	Heath peat	0-3	.531	1.162	.41	1,548	378	360	117	110	41	8.8	4.0
	do	3-6	.851	1.047	.51	1,491	708	318	359	155	77	8.4	3.5
	do	6-9	.890	1.047	.59	1,375	746	220	355	128	70	8.4	
	do	9-12	.800	1.044	.72	1,473	698	187	315	113	82	8.3	
	do	12-15	.936	1.047	.58	1,463	794	237	364	127	80	7.8	
Belle Glade, Fla.	do	15-18	.080	1.053	.40	1,227	753	258	362	130	75	8.0	3.1
	Sedimentary peat	21-30	1.047	1.083	.56	1,105	348	157	211	112	57	5.9	3.5
	White cedar forest peat	30-42	1.158	1.074	.90	1,557	643	162	346	101	83	7.8	3.7
	Saw-grass peat	0-1		1.005	.34	1,507	514	512	180	169	23	15.8	5.3
	do	4-6	.593	1.186	.45	1,563	1,280	515	440	250	81	13.8	6.2
Miami Canal Lock, Fla.	do	32	.072	1.036	.71	1,580	1,050	338	402	216	87	15.3	6.3
	Saw-grass peat, with sedimentary admixture.	40	.043	1.026	.57	1,522	1,455	427	478	211	88	13.0	6.3
	do	63	.085	1.039	.30	1,560	1,255	432	446	215	80	14.3	6.7
	Saw-grass peat	94-106	1.028	1.024	.51	1,400	1,485	392	501	204	87	13.4	7.1
	Sedimentary (custard-apple) peat.	15-30	.903	1.109	1.21	1,981	414	195	239	110	82	11.3	6.2
Clewiston, Fla.	do	42-48	1.034	1.048	.69	1,551	616	303	204	78	14.1	5.9	5.8
	do	62-68	1.019	1.044	.90	1,598	693	262	320	161	85	13.9	6.8
	Saw-grass peat	0-1		1.042	.39	1,555	911	561	339	192	74	14.0	5.5
	do	10-16		1.028	.73	1,510	1,300	370	488	216	90	15.1	5.8
	do	20-26		1.054	.58	1,610	905	309	314	165	82	12.2	5.9
Monroe, Wash.	Saw-grass peat (sandy)	30-36		1.167	.83	2,161	230	107	91	46	57	4.2	6.1
	Woody sedge peat	0-6		1.105		1,512	300	299	108	111		10.3	4.6
	Herbaceous-sedge peat	10-16		1.031		1,469	1,024	577	414	228		10.2	4.5
	Tule-sedge peat	18-24		1.041		1,534	1,015	484	388	223		11.2	5.2

¹ The weight of a cubic centimeter of peat in the natural condition.

The apparent specific gravity in the saturated condition is always greater than unity but approaches unity more closely as moisture-holding capacity increases. The average value for the Maine samples is 1.016; for the North Carolina samples, 1.070; for the Florida samples, 1.108; and for the Washington samples, 1.059. The corresponding averages for the absolute specific gravity in the oven-dry condition are 1.510, 1.405, 1.637, and 1.505. It is obvious that an abnormally high value of the absolute specific gravity indicates mineral contamination to a considerable extent.

The ability of a peat to absorb water or hold water may be ascribed to five different phenomena according to Ostwald (23). These are as follows: (1) Water of occlusion, held in pores 1 millimeter or more in diameter; (2) capillary water; (3) colloiddally bound or adsorbed water; (4) osmotically bound water; and (5) chemically combined water. The maximum moisture-holding capacity represents the total of all forms.

The sphagnum peats possess the greatest power to absorb water, but this power decreases somewhat with the depth of the deposit.

The saw-grass peats of Florida also have fairly high moisture-holding capacities where the mineral content is low and the peat has not already been air-dried before sampling as is the case with some of the surface layers. The peat from North Carolina appears to be similar to the so-called custard-apple peat taken from the Miami Canal Lock at Lake Okeechobee, Fla., and the sedge peat from Washington is similar to the saw-grass peats. Columns 1 in Table 1, under maximum moisture-holding capacity and moisture equivalent, give the values for peat in the natural condition at time of sampling and columns 2 give values for the material after being air-dried. Wherever the values in the corresponding columns are the same or nearly the same it indicates that peat was in the air-dry condition when sampled. This is true of the surface of the North Carolina profile, the Belle Glade, Florida, profile, and the Washington profile. It is interesting to compare the moisture-holding capacities in the two columns corresponding to the natural and to the air-dry conditions. An average value for the sphagnum peats shows that 55 per cent of the water which is capable of being held is taken up again after air-drying. The average is 33 per cent for the heath peat from North Carolina, 40 per cent for the Florida peats taken collectively, and 52 per cent for the sedge peat from Washington.

The previously air-dried surface layers were not included in the averages. The capacity to regain the original moisture tends to decrease with depth.

A greater length of time is required for a peat that has been air-dried to again become saturated as already stated, but continued soaking in water beyond the arbitrarily prescribed time of about seven hours has apparently no effect. Portions of the set of samples from Belle Glade and from Miami Canal at Lake Okeechobee were soaked in water after air-drying as has been described, and weighed after being allowed to drain overnight. The soaking was then immediately repeated for 30 hours, followed by draining and weighing. No increase in the moisture-holding capacity was found. One

sample was kept in water for eight days additional to the preliminary soaking and likewise showed no increase in weight.

The moisture equivalent, like the maximum moisture-holding capacity, is less for the air-dried sample than for the sample in the original condition. There is, however, less difference between the two values for surface layers and layers near the surface, as a rule, than for the deeper layers. On an average, the moisture equivalent of the air-dried sphagnum peat is 82 per cent of the original; of the North Carolina peat, 38 per cent; of the Florida Everglades peat, 51 per cent; and of the Washington peat, 56 per cent.

The maximum percentage of shrinkage is calculated from the values for maximum moisture-holding capacity and the apparent specific gravity in the oven-dry condition. The following example will serve to demonstrate the method of calculation:

Maximum moisture-holding capacity = 3.78 per cent.

Apparent specific gravity (saturated) = 1.162.

Apparent specific gravity (oven-dry) = 0.41.

$$\begin{array}{r} 1.162 \\ 3.78 + 1 \\ \hline 1 \\ \hline 0.243 \\ 1 \\ \hline 0.243 \\ 1 \\ \hline 0.41 \\ 4.12 - 2.44 \\ \hline 4.12 \end{array} \begin{array}{l} = 0.243 \text{ gram of oven-dry material in 1 cubic centimeter of saturated peat.} \\ \\ = 4.12 \text{ cubic centimeters apparent volume of 1 gram of oven-dry peat in the saturated condition.} \\ \\ = 2.44 \text{ cubic centimeters apparent volume of 1 gram of oven-dry peat.} \\ \\ \times 100 = 41 \text{ per cent maximum shrinkage.} \end{array}$$

The results are only approximate since the apparent specific gravity determinations of the oven-dry material are themselves only approximate, yet they serve as a fair basis for comparison.

A method that has previously been used by McCool and Weidemann (16, p. 126), consists of sampling a cubic section of a deposit. Measurements of the dimensions were taken before and after drying, and the percentage of shrinkage was calculated. Such values do not necessarily give the maximum shrinkage unless the peat is saturated at the time of sampling, but these investigators were able to distinguish between horizontal and vertical shrinkage.

The sphagnum peat from Maine and the peat from North Carolina are similar in reaction and were found to be the most acid of those studied. The Everglades peats are less acid and, especially in the Belle Glade profile, show a marked decrease in acidity with increasing depth. This is in agreement with the results of another investigator (11, p. 6). The sedge peat from Washington occupies a more or less intermediate position.

RESULTS OF CHEMICAL ANALYSES

ORGANIC CONSTITUENTS

In order to have a true representation of the relative chemical composition of the different peats, it is necessary to calculate results on the basis of 100 per cent of the actual material represented by the component determined. Thus, if the percentage of carbon is deter-

mined in several samples which range in mineral content from 2 to 75 per cent, it is obvious that the results will be meaningless unless the mineral content is taken into account. Undoubtedly a part of the mineral content is in chemical combination with the organic matter. Nevertheless, if its presence is ignored, since it can not be determined, better comparison of the organic material in the different profiles is obtained than if the comparison is attempted without any elimination. For the purpose of studying the changes which have taken place in a profile of a peat deposit and for comparing different deposits, it is essential to present corresponding analyses on as comparable a basis as possible.

The chemical composition of the organic matter as indicated by the various fractions and calculated to the ash-free material is shown in Table 2.

TABLE 2.—Chemical composition of the organic matter of various peats

[Basis—100 parts organic matter]

Location of sample	Description of sample	Depth	Ether soluble	Alcohol soluble	Water soluble	2 per cent HCl treatment			After 2 per cent HCl treatment		H ₂ SO ₄ treatment			Insoluble residue	
						Nitrogen	Hemi-cellulose	Total soluble	Ether soluble	Alcohol soluble	Nitrogen	Cellulose	Total soluble	Nitrogen	Lignin-humum complexes
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Orono, Me.	Sphagnum peat.....	2-4	2.39	4.78	8.02	0.36	25.2	50.64	0.36	1.07	0.06	13.3	17.17	0.20	17.89
	do.....	8-12	2.83	4.95	5.02	.47	24.1	47.47	.32	1.15	.06	17.1	21.26	.23	18.01
	do.....	12-16	3.27	5.16	5.00	.43	24.6	47.92	.29	1.44	.13	15.7	19.61	.31	18.05
Cherryfield, Me.	do.....	2-4	1.98	4.25	6.09	.32	24.3	48.25	.57	1.99	.06	16.9	20.37	.15	18.89
	do.....	5-8	2.55	5.24	8.72	.44	19.4	36.98	.47	1.44	.09	12.9	17.19	.30	27.63
	do.....	8-12	2.39	5.25	5.82	.28	21.3	43.96	.39	2.02	.06	12.7	18.25	.21	22.41
Beaufort, N. C.	do.....	12-16	3.25	6.31	5.39	.35	19.4	39.30	.33	2.00	.21	11.3	14.50	.28	27.93
	Heath peat.....	0-3	1.29	6.11	4.00	.67	10.8	21.77	.45	2.44	.25	5.3	9.36	1.01	40.30
	do.....	3-9	2.11	7.02	3.38	.47	8.0	15.68	.38	2.83	.21	4.9	8.50	.90	55.67
Belle Glade, Fla.	Heath peat with sedimentary admixture.....	12-18	5.16	8.30	1.53	.18	2.0	4.96	.58	3.05	.10	2.1	4.58	.65	68.54
	Sedimentary peat.....	24-30	0.36	7.08	1.48	.13	.7	3.68	.79	5.02	.05	1.7	3.76	.56	65.90
	White cedar forest peat.....	30-42	2.29	0.80	6.10	.43	1.1	16.65	.75	18.95	.16	5.8	18.89	.48	33.87
Miami Canal Lock, Fla.	Saw-grass peat.....	0-4	.44	1.79	4.06	1.33	11.8	27.50	.33	2.52	.01	3.6	9.24	1.87	43.47
	do.....	4-6	.45	2.04	3.56	1.18	10.9	22.90	.37	2.09	.52	4.0	9.33	1.81	48.80
	do.....	32	.42	1.92	2.10	.68	4.4	11.17	.54	2.72	.47	2.0	7.50	2.22	60.10
Clewiston, Fla.	Saw-grass peat with sedimentary admixture.....	40	.40	1.93	2.36	.52	5.1	9.55	.40	2.20	.36	3.2	8.40	1.94	63.60
	do.....	63	.85	2.17	2.78	.60	5.0	8.25	.36	2.13	.35	4.0	7.93	2.07	65.40
	Saw-grass peat.....	94-96	.75	1.98	2.06	.45	3.8	10.88	.85	2.34	.27	2.8	7.94	2.07	59.25
Monroe, Wash.	Sedimentary (custard-apple) peat.....	15-30	.77	2.70	6.13	1.38	3.6	25.84	.53	4.05	.60	1.1	10.18	1.94	39.55
	do.....	42-48	.47	1.71	2.66	.94	4.2	22.53	.40	2.55	.41	1.7	8.48	2.10	46.11
	do.....	62-68	.52	2.07	2.42	.66	4.0	12.83	.43	2.05	.39	2.7	7.39	2.33	59.64
Clewiston, Fla.	Saw-grass peat.....	0-4	.60	1.89	4.64	1.32	8.8	24.02	.43	2.66	.47	4.1	9.19	1.74	46.91
	do.....	10-16	.55	2.01	2.73	.87	6.9	18.15	.36	2.61	.39	3.1	7.78	1.76	55.45
	do.....	20-26	.70	2.27	3.14	.90	9.0	19.00	.46	2.72	.42	3.0	7.83	1.99	53.00
Monroe, Wash.	Saw-grass peat (sandy).....	30-36	1.47	3.25	3.82	.81	3.2	16.62	.93	4.56	.46	4.6	7.23	1.89	55.28
	Woody sedge peat.....	0-6	1.82	7.43	8.89	1.45	8.1	26.65	.59	2.70	.36	2.7	7.30	1.14	35.64
	Herbaceous-sedge peat.....	10-16	2.01	5.67	5.94	1.41	7.0	24.30	.47	2.36	.34	3.2	7.45	1.43	38.16
	Tule-sedge peat.....	18-24	1.75	3.85	7.94	.73	6.0	19.95	.42	3.83	.20	2.7	6.50	.95	50.39

The ether-soluble fraction is greatest in the sphagnum and sedge peats with the exception of two layers in the North Carolina profile containing sedimentary material. The Everglades peats are markedly low in this constituent. The alcohol-soluble fraction follows practically the same relative order of magnitude, the layer of the North Carolina profile containing a sedimentary admixture having the highest solubility. The water-soluble fraction again shows the highest values for the sphagnum and sedge peats, whereas the others show a fairly constant value except for variations in the profiles themselves.

In general, it appears that the ether and alcohol soluble material increases with depth, except in the sedge and the custard-apple profiles, whereas the water-soluble fraction tends to decrease. The white-cedar forest layer in the North Carolina profile is quite different from the other layers in practically all its constituents, but this is to be expected since the material which contributed to its formation is far different from that contributing to the layers above.

The sphagnum peats contain the most hemicellulose, while the other peats show little differences except wide variations within the profiles. The total hydrochloric acid soluble material in general decreases with depth and is roughly about twice the hemicellulose content. The cellulose and the total material soluble by the sulphuric acid treatment also is greatest for the sphagnum peats and decreases with depth in most cases. The ratio of cellulose content to the total soluble in sulphuric acid rapidly diminishes in the more decomposed profiles where the cellulose content is small. A minimum value for the cellulose is found in the white-cedar forest layer of the North Carolina profile. In the Everglades peats the values range between 1 per cent and 4 per cent. Waksman and Stevens (39), however, found some layers entirely free from cellulose.

Repeated extraction of the peats with ether and alcohol, before as well as after treatment with acid, indicates a relatively large increase in the components soluble in these solvents (Table 2). It is possible, as indicated by Van Bemmelen (2, p. 113), that this increased yield is due to the formation of soluble complexes with the acid employed. It seems more reasonable, however, to assume that the material extracted is derived from the interior structure of peat and is not removed by one extraction, however long continued, because of the semipermeable² nature of the cell membranes. The soluble components can not entirely be removed by extraction until after removal of incrusting substances or disintegration of the cells by acid treatment. That this is reasonable is indicated by the fact that simple alternation of nonacid solvents increases the solubility as is shown in Table 3, in which a second extraction by ether, alcohol, and water, without other treatment, is compared with the first extraction. It is, of course, true that acid hydrolysis may liberate certain bases in organic combination and effect decomposition of complexes of the type of glucosides and that the resulting products are soluble in ether or in alcohol.

² No published data on the semipermeable character of peat are known to the authors, but unpublished data now being obtained in this laboratory indicate this to be the case.

TABLE 3.—Comparison between first and second extractions of peat with ether, alcohol, and water

Location of sample	Second ether extraction as percentage of first	Second alcohol extraction as percentage of first	Second water extraction as percentage of first
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Maine.....	10.3	35.4	75.3
North Carolina.....	10.8	21.8	60.3
Florida Everglades.....	42.5	39.8	79.0
Washington.....	16.0	23.6	69.0

The analysis of the organic material as carried out is largely empirical but serves for purposes of comparison. Such fractions as ether, alcohol, and water soluble material of peat have not been thoroughly examined and are largely of unknown composition. This also applies to the acid fractions and particularly to the lignin-humus complex.

There is still considerable doubt as to the character of lignin as found even in natural plants and still greater uncertainty as to its character in peat, but it is believed to have essentially an aromatic and even phenolic character (35). Part of the lignin in peat as determined by the 72 per cent sulphuric acid method includes at least a part of the so-called humus or humic acids, but the determination of the latter is unsatisfactory by any method known. Neither the same quantities nor even the same substances are extracted by equivalent concentrations of sodium hydroxide and ammonium hydroxide and, furthermore, no typical class of organic compounds is extracted by dilute alkali, at least in the case of soil organic matter (10, 25).

The alkali method for the determination of lignin, if used, would correspond more nearly to the humus as ordinarily considered, but this method is not in agreement with the Willstatter and 72 per cent sulphuric acid methods which give nearly concordant results as shown by experiments with corncobs (24).

Thiessen and Johnson (34) have carried out an analysis of a peat profile wherein the lignin and humic matter were determined separately, but no data are available to show to what degree the results obtained by their method of estimation of lignin agree with values obtained by using the 72 per cent sulphuric acid method. The relative proportions of each from the data of these investigators show that in the surface layers the humic matter may be about 50 per cent of the lignin but increases to a value of more than twice that of the lignin in some of the lower layers. The sum of the lignin and humic matter is, however, hardly comparable to the lignin-humus complexes as used in this investigation. In view of the uncertainty of humus determinations it was not considered desirable to make a separation for the purposes of the present investigation. The term "lignin-humus complex" is used, therefore, to convey a more accurate concept of its character than would the term "lignin" itself. It is the final residue after the sulphuric acid treatment, less the ash and crude protein content.

According to recent evidence (22, 35, 37), lignin is, doubtless, the chief contributor to humus in the process of decomposition, whereas cellulose contributes indirectly and only in small amounts.

The complex character of the nitrogen in peat is well illustrated by the results of Morrow and Gortner (19), and by those of Jodidi (14). In the process of peat formation the residual nitrogen becomes less available, and consequently the more decomposed peats show an increased percentage of the total nitrogen in the final residue. The results in Table 4 show the percentages of the total nitrogen in the peat which were found in each of the fractions wherein nitrogen was determined. The sphagnum peat is found to contain the most readily hydrolyzable nitrogen, but the quantity does not greatly exceed that of the sedge peat, particularly of the surface layer. There is considerable fluctuation within the profiles, but there is in most cases a decrease of hydrochloric acid soluble nitrogen with depth. The sulphuric acid soluble nitrogen apparently fails to distinguish between any of the peats, but the insoluble or lignin-humus nitrogen shows essentially the same differences as the hydrochloric acid soluble nitrogen but in the inverse order. The sphagnum and sedge peats show the lowest percentage of residual nitrogen, and in the others it is markedly higher. In the lowest stratum of the Belle Glade profile as much as 72.6 per cent of the nitrogen is in this very resistant form.

TABLE 4.—Solubility of nitrogen in peat as percentage of total nitrogen

Location of sample	Description of sample	Depth	HCl	H ₂ SO ₄	Insoluble N	Remain- der of N (soluble in ether, alcohol, and water)
			soluble N	soluble N		
		Inches	Per cent	Per cent	Per cent	Per cent
Orono, Me.	Sphagnum peat.....	2-4	46.2	7.7	25.8	20.5
	do.....	5-12	33.4	6.8	26.2	13.6
	do.....	12-16	44.3	13.4	32.0	10.3
Cherryfield, Me.	Sphagnum peat.....	2-4	54.2	10.2	25.4	10.2
	do.....	5-8	46.3	9.5	31.6	12.6
	do.....	8-12	34.2	7.3	25.0	32.9
Beaufort, N. C.	Heath peat.....	0-3	32.2	12.0	48.6	7.2
	do.....	3-9	27.5	12.3	52.6	7.6
	Heath peat with sedimentary admixture.	12-16	18.4	10.2	66.3	5.1
	Sedimentary peat.....	24-30	16.5	6.3	70.0	6.3
	White-cedar forest peat.....	30-42	38.4	14.3	42.5	4.5
Belle Glade, Fla.	Saw-grass peat.....	0-4	32.5	14.4	44.1	9.0
	do.....	4-6	31.5	13.9	48.2	6.4
	do.....	32	18.3	12.6	59.7	9.4
	Saw-grass peat with sedimentary admixture.	49	17.5	12.1	65.3	5.1
	do.....	63	19.1	11.2	65.9	3.6
Miami Canal Lock, Fla.	Saw-grass peat.....	94-96	15.8	9.5	72.6	2.1
	Sedimentary (custard-apple) peat.	17-30	34.1	14.8	47.9	3.2
	do.....	42-48	23.9	10.4	55.0	10.7
Clewiston, Fla.	do.....	62-68	18.7	11.1	66.2	4.0
	Saw-grass peat.....	0-1	35.5	12.0	46.8	5.1
	do.....	10-16	25.7	11.5	51.9	10.9
	do.....	20-26	24.7	11.5	54.7	9.1
Monroe, Wash.	Saw-grass peat (sandy).....	30-36	24.6	14.0	57.4	4.0
	Woody sedge peat.....	0-6	41.2	10.2	32.4	16.2
	Herbaceous-sedge peat.....	10-18	37.6	9.1	35.1	15.2
	Tule-sedge peat.....	18-24	29.3	8.0	38.2	24.6

The water-soluble nitrogen was not determined, but the values would, undoubtedly, correspond fairly closely to those given for the nitrogen unaccounted for as soluble in ether, alcohol, and water.

The total nitrogen content (Table 5), is considerably higher in the peats containing smaller amounts of cellulose and greater amounts of lignin-humus complexes corresponding to a higher degree of decomposition. This is explained (40) by the fact that microbiological activity in the process of plant decomposition has synthesized relatively large quantities of organic nitrogen from inorganic nitrogen.

TABLE 5.—Elementary composition and proximate analyses of peat

Location of sample	Description of sample	Depth	Elementary composition ¹				Proximate analysis ¹		Ash ²
			C	H	O	N	Volatile matter	Fixed carbon	
		<i>Inches</i>	<i>P. d.</i>	<i>P. d.</i>	<i>P. d.</i>	<i>P. d.</i>	<i>P. d.</i>	<i>P. d.</i>	<i>P. d.</i>
Orono, Me.	Sphagnum peat	2-4	50.32	6.08	42.82	0.78	78.69	21.31	4.47
	do.	5-8	50.12	6.25	42.90	.73	79.57	20.43	4.26
	do.	8-12	52.23	6.03	40.86	.86	77.33	22.67	2.29
	do.	12-16	51.78	6.05	41.20	.97	77.38	22.62	1.51
Cherryfield, Me.	Sphagnum peat	2-4	51.16	5.87	42.38	.59	76.70	21.21	2.31
	do.	5-8	52.79	5.80	40.46	.95	71.70	28.30	1.80
	do.	8-12	52.76	5.79	40.63	.82	70.92	29.08	1.55
	do.	12-16	55.93	5.57	37.61	.89	67.46	32.54	1.88
Beaufort, N. C.	Heath peat	0-3	57.57	5.70	34.65	2.08	59.77	40.23	7.17
	do.	3-9	59.20	5.33	33.76	1.71	61.03	38.37	2.33
	Heath peat with sedimentary admixture.	12-18	64.40	5.38	29.24	.98	39.18	49.82	2.08
	Sedimentary peat	24-30	65.70	6.29	27.31	.79	61.42	38.58	6.74
Belle Glade, Fla.	White-cedar forest peat	36-42	55.97	5.61	38.20	1.12	61.11	38.89	27.05
	Saw-grass peat	0-4	56.82	5.47	33.47	4.24	66.57	33.43	8.54
	do.	4-6	58.48	5.55	32.22	3.75	65.38	34.62	6.67
	do.	32	61.79	5.51	28.98	3.72	65.01	34.99	10.67
Miami Canal Lock, Fla.	Saw-grass peat with sedimentary admixture.	49	62.71	5.40	28.92	2.97	61.44	38.56	7.60
	do.	63	63.12	5.54	28.20	3.14	64.70	35.21	8.63
	Saw-grass peat	94-96	60.12	5.57	31.46	2.85	64.54	35.36	17.82
	Sedimentary (custard-apple) peat.	15-30	52.45	5.85	37.65	4.05	71.86	28.14	47.57
Clewiston, Fla.	do.	42-48	53.21	5.01	37.85	3.93	67.47	32.53	10.27
	do.	62-68	58.24	5.60	32.64	3.52	67.49	32.51	22.92
	Saw-grass peat (sandy)	0-4	56.82	5.61	33.55	3.72	68.75	31.25	11.46
	do.	10-16	58.70	5.47	32.44	3.39	64.97	35.03	7.73
Monroe, Wash.	do.	20-26	61.07	5.65	29.64	3.64	65.10	34.90	28.07
	Saw-grass peat	30-36	58.30	4.87	33.54	3.29	63.73	36.27	75.32
	Woody sedge peat	0-6	56.42	6.11	33.95	3.52	72.20	27.80	10.84
	Herbaceous-sedge peat	10-16	56.60	6.06	33.59	3.75	70.35	29.65	6.51
	Tule-sedge peat	18-24	57.61	6.59	34.31	2.49	67.33	32.67	11.49

¹ Basis, 100 parts organic matter.² Basis, 100 parts dry peat.

The elementary composition and proximate analyses are shown in Table 5. The total carbon content is least for the sphagnum peats. The sedge and custard-apple peats are similar in total carbon and also in volatile and fixed carbon and are not far different from the sphagnum peats in the latter values. The North Carolina profile has the greatest amount of fixed carbon and correspondingly the least amount of volatile matter. In total carbon only, the sedimentary layer and the layer with sedimentary admixture of this profile show the highest values. The carbon tends to increase slightly with increase in depth except that in several cases a lower layer falls out of line and may even have a less amount than the surface layer.

This slight variation in the composition of the organic matter shows little evidence of tendency toward lignite formation and indicates little microbiological action with age of deposit. There is fair agreement between the results obtained for fixed carbon and total carbon so far as their indications are concerned.

It must be remembered that in the data on the organic matter the values are expressed on a basis of 100 parts of organic material instead of the entire material. The latter data would give far different and less significant results.

A graph which shows the relations between fixed carbon, lignin-humus complexes and cellulose in the different layers of the profiles is given in Figure 1.

The fixed carbon has values greater than those for lignin-humus complexes in the Maine peats, but the relative order of magnitude of these two values is reversed for all other profiles examined. In general the fluctuations of values of lignin-humus complexes within the profile correspond to similar fluctuations of the fixed-carbon value to a more or less marked degree. This seems to indicate that the lignin-humus complexes form the greater part of the non-volatile or fixed carbon constituent. Cellulose is relatively high only in the sphagnum peats and shows no great variation in any profile, at least to the depths represented. The Washington peat apparently occupies an intermediate position between the Maine peats on the one hand and the North Carolina and Florida peats on the other.

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The analyses of the ash shown in Table 6 indicate that the ratio of alumina to iron oxide is relatively much higher in the sphagnum peat than in the Everglades peats. It is also relatively high in the peat profile from North Carolina and is as high in the sedimentary and white-cedar forest layers as in the sphagnum peat. The sedge peat from Washington is similar to the Florida peat in this respect, but the ash is much richer in both constituents.

The ash of the sphagnum and sedge peats is on the average richer in phosphorus pentoxide than that of the others which show similar values. The Everglades peats are generally high in lime content, and in several layers it amounts to almost 50 per cent of the ash, on account of limestone formations underlying the deposits. The sphagnum and sedge peats are similar, with values in the neighborhood of 15 to 20 per cent, and the ash of the North Carolina profile contains on the average the least amount of lime of the profiles examined.

The constituents, magnesium oxide, sulphuric anhydride, and titanium oxide, do not show any marked differences between profiles, but there are considerable variations within the profiles. The ash of the sphagnum peat appears to be the richest in alkalis, the ash of the others being more or less similar in these constituents.

Manganese has been concentrated in the surface layers wherever these are shown. This phenomenon is also characteristic of certain ordinary soils as pointed out by Robinson (27) of this bureau.

TABLE 6.—Chemical composition of peat ash

Location of sample	Description of sample	Depth	Inorganic constituents of the ash ¹													
			Soluble SiO ₂	Insoluble SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	TiO ₂	P ₂ O ₅	CaO	MgO	SO ₃	CO ₂	Na ₂ O	K ₂ O	MnO	Total
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Orono, Me.	Spagnum peat	2-4	9.80	41.95	6.77	14.85	0.62	2.21	10.55	5.21	4.63	0.81	1.87	0.71	0.37	100.25
	do.	5-8	6.09	45.61	3.84	18.60	.56	2.96	9.70	5.70	5.40	-----	1.00	1.10	-----	100.50
	do.	8-12	7.78	24.03	4.15	11.58	.42	4.53	24.31	9.86	5.94	4.87	1.02	1.25	.13	98.97
	do.	12-16	7.47	20.90	3.58	9.50	.39	5.06	27.10	9.15	6.50	8.97	.85	.52	.11	100.10
Cherryfield, Me.	Spagnum peat	2-4	8.77	20.72	3.34	12.23	.45	2.83	22.81	9.36	7.07	0.25	2.27	3.29	.90	100.89
	do.	5-8	8.33	27.94	4.84	18.22	.50	5.09	13.69	12.02	7.10	.96	2.40	3.22	.12	100.09
	do.	8-12	-----	20.29	5.50	11.16	.53	7.76	12.63	20.08	8.13	1.11	.91	1.73	.06	99.60
	do.	12-16	-----	34.61	5.24	14.33	.61	1.04	12.45	18.33	7.55	.34	4.57	1.14	.05	100.26
Beaufort, N. C.	Heath peat	0-3	15.03	49.35	4.24	10.63	.63	1.86	8.10	4.50	3.20	.04	.70	.60	.06	99.78
	do.	3-9	12.12	34.00	4.50	9.96	.58	3.10	10.20	13.50	8.80	.75	1.30	1.30	.01	100.18
	Heath peat, with sedimentary admixture.	12-18	2.66	68.54	1.85	9.10	2.61	1.55	5.00	3.75	4.00	.20	.48	.15	-----	100.58
	Sedimentary peat	24-30	5.36	66.46	2.16	10.01	1.15	.50	6.30	4.10	4.70	-----	.50	.30	(?)	101.54
Belle Glade, Fla.	White cedar forest peat	30-42	4.34	73.02	3.20	13.96	1.34	.50	1.30	7.00	1.00	.44	.30	.60	.01	100.71
	Saw-grass peat	0-4	3.26	22.70	2.10	1.74	.16	2.55	34.75	4.20	0.35	20.12	.06	.90	.16	99.55
	do.	4-6	4.80	4.31	2.10	.81	.39	1.50	44.15	7.30	7.60	25.84	.32	.44	.07	99.63
	do.	32	2.22	1.24	1.60	2.08	.22	.35	48.85	5.95	0.50	30.42	.46	.20	.01	100.10
Miami Canal Lock, Fla.	Saw-grass peat, with sedimentary admixture.	49	1.02	.77	1.65	.05	.15	.40	49.05	6.75	0.30	33.58	.78	.18	-----	101.23
	do.	63	1.30	.76	2.30	.36	.14	.50	48.70	6.15	0.70	32.12	.72	.24	-----	100.05
	Saw-grass peat	94-96	17.44	27.06	3.20	3.10	1.70	.35	21.75	5.85	4.30	9.44	.42	.48	-----	100.09
	Sedimentary (custard-apple) peat	15-30	33.36	26.27	10.00	12.12	1.58	.40	5.45	7.30	2.25	.08	.42	.96	-----	99.63
Clewiston, Fla.	do.	42-48	15.58	20.19	7.25	7.39	.71	1.05	22.40	5.85	11.55	6.08	.50	.36	.02	99.59
	do.	62-68	1.62	2.73	7.30	1.78	.14	1.00	36.70	6.25	34.95	0.86	.58	.02	.03	99.94
	Saw-grass peat	0-1	2.68	10.62	8.15	2.17	.18	2.75	38.95	2.90	9.00	21.00	.26	.20	.03	99.49
	do.	10-16	1.94	3.54	7.10	.95	.15	1.55	49.50	4.75	12.85	16.80	.26	.10	(?)	99.49
Monroe, Wash.	do.	20-26	1.88	72.94	2.06	1.33	.09	-----	12.42	1.00	2.59	4.83	.42	-----	99.56	
	Saw-grass peat (sandy)	30-36	1.42	95.08	.55	2.24	.05	.10	2.26	.04	.60	.00	.50	-----	101.44	
	Woody sedge peat	0-6	10.28	24.00	28.20	11.40	.45	3.95	11.90	2.33	4.47	1.20	-----	.86	.80	99.84
	Herbaceous sedge peat	10-16	8.04	9.65	24.90	15.33	.50	3.83	21.85	1.56	7.60	4.37	.83	.43	.80	100.12
Tule-sedge peat	18-24	11.27	22.54	16.49	16.71	.68	1.85	17.00	3.08	3.56	3.76	2.12	.59	.61	100.26	

¹ Basis—100 parts ash.² Total SiO₂.³ Trace.⁴ Al₂O₃ plus P₂O₅.

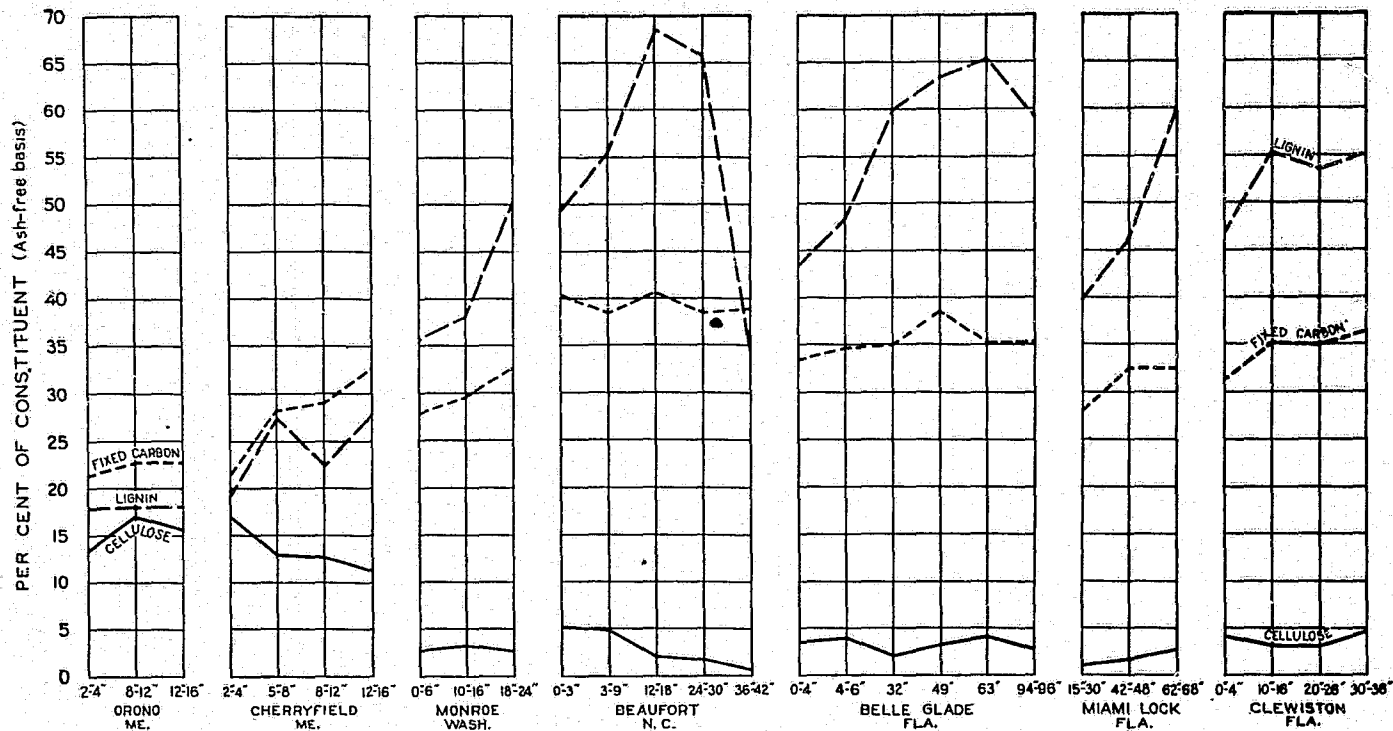


FIGURE 1.—Graph showing relationship between certain organic constituents in various peats with respect to location and depth

Some of the results of the ash analyses are illustrated in Figure 2. Wide variations in the total ash content of peat (Table 5) as well as variations in the character of the ash (Table 6) are explained by the fact that peat in its formation is subject to mineral contamination largely by wind-blown material, as in the case of the sphagnum peats or by dissolved matter carried by ground waters, as in the case of the Everglades peats. Leaching also may take place to varying extent and alter the relative proportions of certain elements.

The presence of carbon dioxide in the ash is not necessarily an indication of the presence of carbonates in the peat, since carbonates of the metals are formed during ignition and the temperature of ignition was not sufficiently high to effect complete decomposition

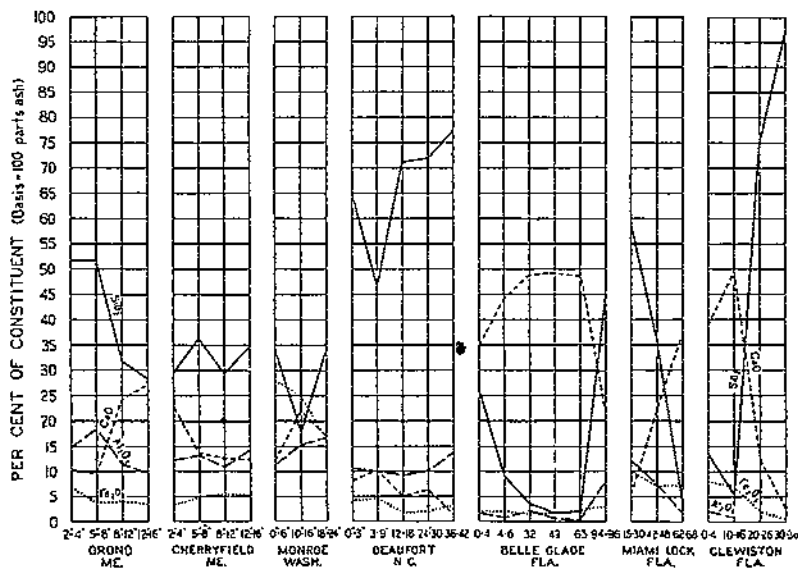


FIGURE 2.—Graph showing relationship between certain inorganic constituents in various peats with respect to location and depth

of the carbonates so produced. No determinations of carbon dioxide were made on the original peat.

The data in Table 6, as well as those previously mentioned, must not be confused with mineral analyses on the usual basis. The values given can readily be converted to the basis of 100 parts of dry peat by multiplying by the total ash content (Table 5) and dividing by 100.

BACTERIAL ACTIVITY AND DECOMPOSITION

It is not within the scope of this bulletin to discuss the bacterial activity in peat with any degree of thoroughness. There are certain comments, however, which it is believed should be made. Evidence has been presented for and against the presence of bacteria in peat and reviewed by Waksman and Stevens (40), but the preponderance of recent evidence points to the fact that cultures of bacteria may be obtained even to considerable depths, and this fact is accepted by most investigators at the present time.

There is not, however, complete agreement as to the functions of these bacteria in peat deposits. Thiessen and Johnson (34) assert that bacteria are functioning to all depths of a deposit, whereas on the contrary, others (12, p. 94; 13) point out certain toxic conditions of peat bogs. Experiments carried out in the present investigation and subsequently cited by Robinson (28) show little or no production of gas from various layers of peat submerged in water for a period of a year and none even when the peat was inoculated with a very active submerged soil. This may be due to a lack of available nutrients or to a toxic condition, or both, assuming that evolution of gaseous products necessarily accompanies bacterial activity in peat. Even a surface layer has in this period produced only a few cubic centimeters of gas, which was given off during the first month after the peat was submerged, and has remained without further evolution of gas for more than a year.

These facts support the ideas of Jeffrey (13) and others as to the permanence of peat once it is permanently covered by water and aerobic bacteria have ceased to function.

It has been shown by Allison and his coworkers (1) that the addition of very small amounts of copper sulphate to certain peat lands alters a substance toxic to plants. An amount of copper sulphate approximately equivalent in proportion to the amount necessary for application to peat land (50 pounds per acre) was introduced into a sample of peat showing no activity either before or after being inoculated with the submerged soil suspension and allowed to stand for a time, and then again inoculated. There was no effect with reference to evolution of gas, so one must conclude that if such a solution were toxic to bacteria the cause was not removed by the copper sulphate in the concentration used, unless both factors, lack of nutrients and toxicity, were operative. This conclusion is in agreement with Waksman and Stevens (39), who state that "copper has no effect upon the microbiological activities in the peat itself."

Smith (32) has isolated a substance which is soluble in alcohol, and which was precipitated by copper sulphate. It was shown that the presence of this compound had certain undesirable effects on plant growth. Further information, however, as to the nature of this substance is apparently not available.

This investigation has shown, as have also the investigations of Waksman, that successive layers within a profile may show wide variations in degree of decomposition as indicated by varying amounts of lignin-humus complexes. In order to explain these variations it is necessary to consider the mechanism by which a peat deposit is laid down and the prevailing climatic conditions governing the formation of different strata. According to Dachnowski-Stokes (4), the stratification of a peat deposit is directly related to the nature of the plant remains which have contributed to the particular layers and to the changes brought about by moisture and other environmental conditions during the formation of these layers.

Furthermore, there is evidence (4, 9, 13) to show that a "perpetual water cover effectually guarantees the integrity of plant remains." The peat profile as found thus presents a definite historical record of the type of vegetation and of the climatic conditions involved in its formation, and in this process anaerobic bacteria play only a

minor rôle. Spores are, however, present which may develop under suitable environment and account for the cultures of bacteria obtained from even very deep peat deposits.

The lignin-humus content of the organic matter may be used as an index of degree of decomposition to some extent since it represents a residue or an accumulation of substances synthesized by bacterial action and resistant to further decomposition at the time of peat formation. It may be said with a fair degree of certainty that varying values of this constituent within a profile are due in part to varying successive types of vegetation and are existent partly as the result of fluctuating climatic conditions during the process of formation rather than to changes taking place with age in a deposit once permanently submerged. Likewise an abnormally high carbon content of the organic matter in a given stratum probably indicates that aerobic bacteria were capable of functioning for a longer period of time. There is no evidence presented by the data in support of any theory of lignite formation from present peat deposits under conditions now existing. Peat is believed instead to be indefinitely preserved by a permanent water cover.

GENERAL DISCUSSION AND CONCLUSIONS

The preceding data shows that the types of peat from northern regions of the United States, which differ in botanical composition and climatic environment from those of southern States, show in general corresponding differences in physical and chemical properties to the extent that these types are examined. The sphagnum peat from Maine and, to less degree, the sedge peat from Washington are distinctly different from the other varieties examined. In many properties the North Carolina and Florida peats are similar. Differences within a given profile are often of such magnitude that the importance of the past history of the profile can not be overemphasized. A layer is often found in a given profile which was necessarily formed under entirely different climatic environment than were the layers above, the formation of which corresponds more nearly to present conditions.

In physical characteristics differences are shown for the most part by the moisture relations, including maximum moisture-holding capacity and moisture equivalent. The sphagnum peat is quite distinct from all others except in the lowest layer of the sample from Orono, Me., where a woody type of peat, formed under entirely different conditions, is found.

The chemical characteristics of the organic matter also show the sphagnum peat to be of quite different composition due to the fact that it consists of the stems and leaves of mosses and is less decomposed than any of the other peat materials, composed either largely of a network of root and rhizomes, or of the herbaceous residue which forms sedimentary peat. The North Carolina profile, especially the sedimentary and white cedar forest layers shows the highest alcohol solubility, including the alcohol fraction obtained after acid treatment, and the lowest hemicellulose content and is distinct in these respects. The sedge peat from Washington appears to be in a more or less intermediate stage of decomposition between the

sphagnum peat on the one hand and the saw-grass and sedimentary peat on the other. The organic matter of the three Florida profiles appears to be quite similar; in each case taking into account the great variations within a profile itself.

The differences in the character of the organic matter are shown for the most part by the ether and alcohol fractions, hemicellulose and cellulose, lignin-humus complexes, and the nitrogen soluble in the various fractions. Emphasis should be placed on the need for further research as to the exact nature of the lignin-humus complexes. Such research would, undoubtedly, show further differences between peats originating from different materials and under varying conditions.

Analyses of the ash show, perhaps, greater differences between profiles in the ratio of alumina to iron oxide, lime, and alkali content than in any other constituents. Here, again, there is considerable fluctuation within profiles which tends to obscure differences between profiles. The sphagnum peats have a characteristically high ratio of alumina to iron oxide that is possessed by no other peats examined except the sedimentary and white-cedar forest layers of the North Carolina profile. In lime content the Everglades peats are markedly high, and the heath peat is very low. The sphagnum peat, especially that of the Cherryfield profile has an ash comparatively rich in alkalis. The soluble silica apparently has no particular significance.

It must be remembered that the analyses as given show the relationships between constituents on a common basis and should not be confused with the tabulations of results on the usual basis.

SUMMARY

There is presented a comparison of peat materials and profiles of several deposits, which differ widely in type of vegetation and in geographical location, using uniform methods of examination of a wide range of physical and chemical properties.

The properties or characteristics that were determined include apparent and true specific gravity, moisture relations, maximum shrinkage, reactions, a fractional analysis of the organic matter, elementary and proximate composition, mineral constituents of the ash, and behavior of certain peat samples when submerged under anaerobic conditions.

All the physical characteristics were determined directly upon the peat samples as received from the field and in the case of the moisture relationships were calculated on the basis of the material dried at 105° C. The chemical characteristics, with the exception of the hydrogen-ion concentration and total ash content, were determined on the basis of 100 per cent of the material represented by the analysis.

The physical properties which are shown to be the most useful in distinguishing between different types of peat include the maximum moisture-holding capacity and moisture equivalent. Other properties show differences to a less marked extent.

The chemical characteristics or analyses that have served best to segregate the various profiles include the ether and alcohol fractions, hemicelluloses and cellulose, lignin-humus complexes, soluble

and insoluble nitrogen, and ash composition, including values for lime, alkalis, and sesquioxides in particular.

The sphagnum peats from Maine and, to a lesser degree, the sedge peat from Washington, are shown to be distinctly different from the other peats examined. In certain respects the sedge peat from Washington appears to be similar to the sphagnum peats but in other properties it resembles the woody saw-grass or sedimentary peats from the South. Variations within profiles frequently tend to obscure differences between profiles.

The somewhat wide range of physical and chemical properties between different strata within a deposit is due to varying successive types of vegetation and climatic factors involved in the transformation of vegetable matter to peat through microbiological activity.

The data do not furnish evidence in support of any theory of lignite formation from present peat deposits. Peat is believed rather to consist of indefinitely preserved layers of plant remains once permanently submerged by water, and its degree of decomposition is indicated to some extent by the lignin-humus complexes.

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