PEAT IN THE DISMAL SWAMP, VIRGINIA AND NORTH CAROLINA.[1]

By C. C. Osbon.

GEOGRAPHY.

The Dismal Swamp district is in the Coastal Plain of southeastern Virginia and northeastern North Carolina. (See Pl. IV.) It lies roughly between parallels 36° 15′ and 36° 45′ N. and meridians 76° 5′ and 76° 35′ W., and approximately includes Norfolk County and the eastern part of Nansemond County, Va., and Perquimans, Pasquotank, Camden, and Currituck counties, N. C. As the limits of the swamp depend largely upon rainfall and vegetation, as well as topography, they are rather irregular and are not sharply defined.

The swamp is traversed from Deep Creek, Va., to South Mills, N. C., by the Dismal Swamp Canal and is cut by numerous smaller canals and ditches radiating from Lake Drummond. The Norfolk Southern Railroad skirts the eastern, southern, and western parts of the swamp, and its north end is crossed by the Virginian, Seaboard Air Line, and Norfolk & Western railroads.

The total area of the Dismal Swamp is about 2,200 square miles, of which a little more than 700 square miles has been drained by the Dismal Swamp Canal and other ditches. A large part of the swamp is owned by the Roper Lumber Co., Norfolk, Va., and by the Richmond Cedar Works, Richmond, Va.

The region as a whole is but sparsely populated, and the chief industries in the reclaimed areas are lumbering and agriculture.

GEOLOGY.

The peat deposits of the Dismal Swamp lie in shallow basins that originated in an extensive depression of the Columbia group of formations. During the deposition of these formations the mouth of James River was some distance southwest of its present mouth,[2]

[1] Some of the field work upon which this report is based was done by E. K. Soper.
[2] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), pl. 1.

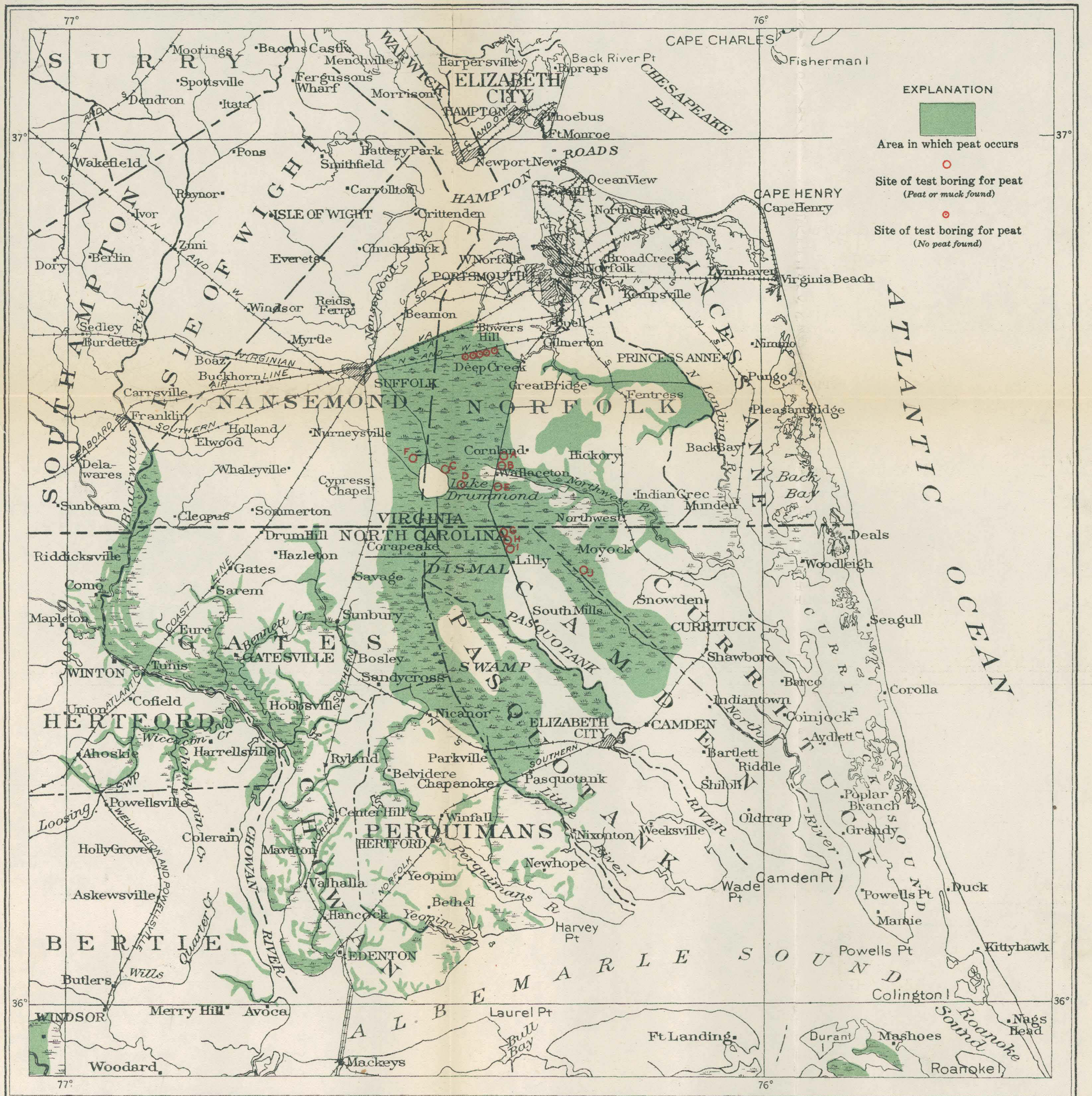
and the sediment it laid down probably formed a bar or delta east of the swamp. When the land was subsequently uplifted the mouth of the James was diverted to its present position, and between the terrace formed by its delta and the Nansemond escarpment there remained a large, poorly drained depression in the surface. The normal annual precipitation of the region is about 52.08 inches, and the average humidity is 73 per cent. Thus favored by topographic and climatic conditions, the surface was soon saturated or covered with water and luxuriant vegetation, and it has remained in substantially the same state since that time.

While the swamp was young most of the peat was formed below water level and the deposits were largely of the filled-basin kind. Later many basins in the region were filled to the general level of the surrounding country by vegetal accumulations, and much of the surface water was drained off through the Dismal Swamp Canal and subsidiary ditches. Thus the Green Sea, which was originally connected with the main morass, has been detached by the draining of the intervening area. Many marginal sections have also been reclaimed for agricultural use by small ditches and are no longer swampy, except in very wet weather. However, the greater part of the swamp is still so poorly drained and so choked with plant growth that it is continually saturated or covered with water. The average depth of the water is only a few inches. In the western part the water is in places 2 feet deep, and peat is still forming there under water. In the eastern part the water seldom stands above ground, although in many places it keeps the surface so highly saturated that peat is still accumulating. In the thoroughly drained sections the formation of peat has been superseded by that of leaf mold.

FLORA.

The Dismal Swamp lies at the junction of the coniferous and deciduous forest regions of the eastern coast of the United States. Its flora comprises plants of a great number of species and is interesting because it shows a mingling of the northern and southern land floras. In the earlier stages of peat formation algae and mosses probably grew profusely in its shallow waters, building up deposits of fine-grained peat, which is now found in the bottoms of the basins. As the remains deposited by these plants accumulated the basins became shallower, enabling the pondweeds (*Potamogeton*), the water lilies (*Castalia* and *Nymphaea*), and the lake bulrush (*Scirpus*) to establish themselves temporarily.[1] In some of the higher parts of the morass the bog-meadow and bog-heath stages, in which the *Carex* and *Andromeda-Ledum* associations predominated, may have followed in small areas. As the surficial depres-

[1] Davis, C. A., U. S. Geol. Survey Bull. 376, p. 13, 1909.



MAP OF SOUTHEASTERN VIRGINIA AND NORTHEASTERN NORTH CAROLINA

Showing distribution of peat and location of test borings in Dismal Swamp

Scale $\frac{1}{500,000}$

10 0 10 20 Miles

1919

sions were relatively shallow, and as logs are found in nonfibrous peat at depths of 5 to 10 feet in many sections of the swamp, it is believed that deciduous and coniferous trees more or less fully superseded the other flora at an early date and contributed the greater part of the dead vegetation from which the peat deposits of the region were formed.

The present flora of the Dismal Swamp includes aquatic plants, the fern and peat-moss association, deciduous and coniferous trees, and associated undergrowth. Nearly the whole region is forested, and the plant associations are so intimate that it is difficult to delimit the distinct formations. However, the following ecologic classification, which follows roughly the classification used by Schenck in "Biologie der Wassergewächse," shows the most abundant plants that are now contributing to the formation of peat:

AQUATIC PLANTS.

Submersed:
- Utricularia spp.
- Riccia fluitans.
- Philotria canadensis.
- Sphagnum kearneyi.
- Callitriche heterophylla.
- Juncus repens.
- Isnardia palustris.

Floating on the surface:
- Spirodela polyrhiza.
- Castalia odorata.
- Nymphaea advena.
- Nelumbo lutea.
- Potamogeton lonchites.
- Callitriche heterophylla.

Rising above the surface:
- Sparganium androcladum.
- Myriophyllum heterophyllum.
- Woodwardia virginica.
- Eriophorum virginicum.
- Decodon verticillatus.
- Limodorum tuberosum.
- Sphagnum cymbifolium.

BLACK GUM ASSOCIATION.

- Water ash (Fraxinus caroliniana).
- Rattan (Berchemia scandens).
- Yellow jessamine (Gelsemium sempervirens.)
- Cross vine (Bignonia capreolata).
- Water gum (Nyssa biflora).
- Bald cypress (Taxodim distichum).
- Red maple (Acer rubrum).
- Cotton gum (Nyssa aquatica).

WHITE CEDAR ASSOCIATION.

- Loblolly pine (Pinus taeda).
- Sweet bay (Magnolia virginiana).
- White cedar (Chamaecyparis thyoides).
- Shrubs (Ericaceae association).
- Cane (Arundinaria macrosperma).

Aquatic plants are found in nearly all the wetter parts of the swamp, notably in some of the abandoned ditches, which have been completely filled with them. However, in areas of dense shade they make little headway and are of minor importance in the formation of peat.

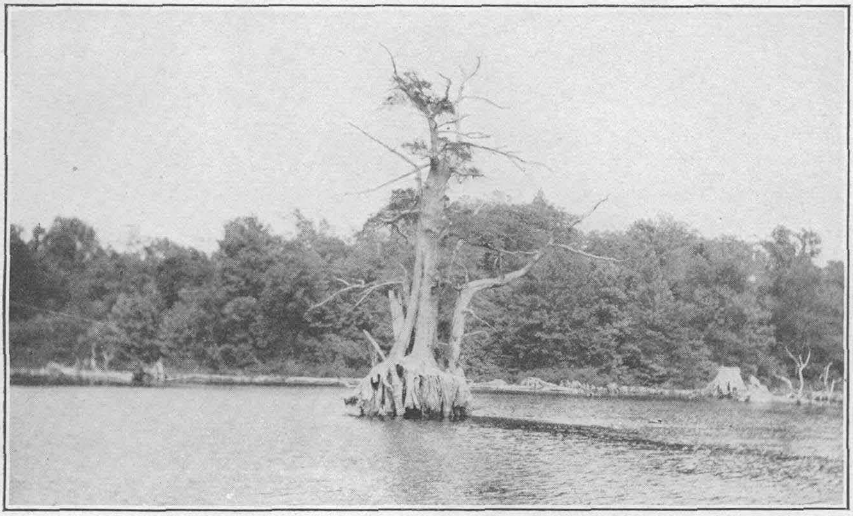
Ferns and peat mosses are found in the open parts of the region. *Sphagnum cymbifolium* grows in the shallow water and among the stipes of the *Woodwardia* in the higher parts of the peat area. The roots are usually submerged, and the stems, which range in length from 6 to 18 inches, rise above the surface.

The water gum, locally known as black gum, and white cedar or juniper forest associations predominate throughout the region and contribute the greater part of the dead vegetation that is now accumulating. The densely forested wetter part of the morass, especially the area surrounding Lake Drummond, is known as the black-gum swamp. (See Pl. V, *A*.) It is characterized by the profuse growth of black gum and its associated undergrowth, although red maple is also abundant. Here immense quantities of peat are now accumulating. The bald cypress is also still found in some parts of the black-gum swamp but probably was more abundant in earlier years. In fact, the most striking feature of the region is the weird aspect presented by the cypress knees and the belt of old weathered cypress stumps standing on the margin of Lake Drummond and hung with Spanish moss. These stumps, which have survived the attacks of the elements for many years, and the numerous well-preserved cypress logs that are encountered several feet beneath the surface indicate that cypress formerly contributed much more dead vegetation to the peat deposits than now.

The open, light parts of the morass, known locally as juniper swamp, are largely occupied by the white-cedar association. In earlier years these areas were completely forested by white cedar, but now, owing in part to the work of man, many of them bear a growth of shrubs and cane. (See Pl. V, *B*.)

ORIGIN.

Peat is incipient coal. It is the organic residuum resulting from the arrested decomposition of leaves, twigs, roots, trunks of trees, shrubs, mosses, and other vegetation in areas continually covered or saturated with water. It may be identified as a dark-colored soil found in bogs and swamps, commonly called muck, although technically the term "muck" should be restricted to soil in which the quantity of inorganic mineral nearly equals or exceeds that of the organic matter. In mild or warm climates the formation of peat is directly dependent upon abundant rainfall and luxuriant plant growth and is indirectly regulated by topographic and climatic conditions. Basins in which peat has accumulated are found in the glaciated regions of New England and of the Great Lake States and in areas like those of the Atlantic and Gulf Coastal Plain, where the seacoast has subsided and bars or deltas have formed inclosed ponds or land-locked lagoons and estuaries. The most extensive peat deposits of the United States are in these regions. Water is next in importance to topography in the formation of peat. It performs a



A. BLACK-GUM AND BALD-CYPRESS SWAMP ON THE EASTERN SHORE OF LAKE DRUMMOND.

B. ASSOCIATION OF SHRUBS AND SMALL TREES GROWING IN PEAT IN THE OPEN OR LIGHT SWAMP NEAR DISMAL SWAMP CANAL.

TYPES OF PEAT-FORMING PLANT ASSOCIATIONS IN DISMAL SWAMP.

twofold function, enabling plants to grow profusely and protecting their remains from complete decay. In order that water may accumulate on the surface abundant rainfall and a humidity sufficiently high to prevent rapid evaporation are necessary. Where rainfall is heavy and the drainage is arrested or greatly retarded by plant growth peat sometimes forms even on level areas and gentle slopes, especially in cold or very humid climates. In these places, although the water seldom rises above the ground, it is progressively elevated as the plant remains collect, and the water table is always near the surface.

Topographic and climatic conditions that are unusually favorable for the accumulation of peat exist in the Dismal Swamp region. Many shallow basins and poorly drained level areas choked with dense vegetation are found between the Nansemond escarpment and the terrace plain to the east. Some of these depressions have already been filled with peat to the general level of the surrounding country. The climate is characterized by heavy and well-distributed rainfall, uniformly high humidity, and a temperature sufficiently low to prevent a too rapid evaporation and the complete decay of dead vegetation. The growing season is long, the winters mild, and the sunshine abundant. Thus favored by climate and moisture the plant growth in the Dismal Swamp is luxuriant, being so dense in many places that it can not be penetrated by man without great difficulty. The central part of the swamp is so densely forested that the sun rarely shines upon the ground, and the quantity of dead vegetation that has accumulated is immense. In certain of the open parts of the swamp the canes grow very closely together, and in places the leaves, falling among them, accumulate to the thickness of 1 foot each year. Next to the trees and the larger shrubs the canebrakes are probably the greatest contributors to the vast quantity of organic matter which yearly accumulates upon the surface of the region.

One of the chief substances formed by plants during their growth is cellulose, which is produced from atmospheric carbon dioxide and from water supplied by the roots and which consists of carbon, hydrogen, and oxygen. If the plant débris falls upon drained soil it is immediately attacked by microorganisms and the carbon and hydrogen of the cellulose unite with atmospheric oxygen and form carbon dioxide and water. In other words, if oxidation is unhampered the organic matter will disappear in a relatively short time. If, however, the plant matter falls into water or upon soil saturated with moisture it undergoes a change different from the decay suffered by exposed vegetation. The atmospheric oxygen is largely excluded by the moisture, and the plant substance is partly protected from the attacks of fungi and bacteria. The salient features of the evolution of peat from cellulose are the elimination of hydrogen and oxygen as water and of carbon and oxygen as carbon dioxide and the generation of methane. The evolution of water and methane exhausts the hydrogen more rapidly than the carbon. This is the process of carbonization. If surface conditions are unchanged the process of carbonization is greatly retarded upon the formation of peat, and the accumulation of organic matter may exist indefinitely as peat unless the land is drained and decomposition again begins, or unless the peat is deeply buried beneath superposed deposits, generally muds, sands, limestone, etc., and subjected to pressure, with varying degrees of heat. Lignite, bituminous coal, anthracite, and graphite are succeeding stages in the process of carbonization. It seems, therefore, that most if not all coals were once peats, that most coal fields were formerly swamps, and that the formation of peat in the Dismal Swamp is an existing example of the first stage in the process of coal formation. It has been shown that deposits essentially similar to those of the Dismal Swamp were laid down in many parts of the United States during the Carboniferous period.

DISTRIBUTION.

GENERAL CONCLUSIONS.

The Dismal Swamp covers approximately 2,200 square miles, of which a little more than 700 square miles has been permanently drained to a depth of 3 feet or more by Dismal Swamp Canal and smaller ditches. (See Pl. IV.) Much of the drained land is farmed. In the remaining 1,500 square miles peat deposits ranging in depth from 1 foot to 20 feet are found. The thickest beds lie in the region east and northeast of Lake Drummond, where peat 18 feet deep was exposed by comparatively recent excavations. The peat in this area is black and low in inorganic impurities and is probably the best in the swamp. In general, the depth of the peat gradually decreases toward the edge of the swamp, where the peat finally merges into the sands of the adjoining areas. The eastern border is deeply indented by large tracts that have been drained, cleared, and cultivated. Some peat of value is found in the southern and southeastern parts of the morass, but the northern and western parts contain few deposits large enough to be of commercial importance.

The Dismal Swamp is not entirely covered with peat—in fact, not more than half of it contains peat of commercial value. In some parts of the swamp the peat is too shallow to be worked profitably, and in others it contains so many roots, stumps, and logs that excavation by present methods would be impracticable. In many areas the peat has been destroyed by forest fires. In some of the heavily forested areas peat has never formed to great depths, perhaps because of the presence of excessive surface water and dense shade, which prevented the growth of shrubs, mosses, grasses, reeds, ferns, and other prolific peat-forming plants. From numerous test borings, observations made along the banks of drainage canals, and information furnished by drainage engineers who are familiar with the swamps, it is estimated that the average thickness of the peat is 7 feet. On the assumption that the uncultivated area of the Dismal Swamp is 1,500 square miles, that about one-half of this area is covered with peat averaging 7 feet in depth, and that, according to the usual practice in estimating the tonnage a bog will yield, 200 tons of dry peat per acre-foot may be obtained, then the total available peat in the Dismal Swamp is 672,000,000 tons.

AREAS TESTED.

VIRGINIA.

NORFOLK COUNTY.

The best peat in the Dismal Swamp is found in Norfolk County, Va., in the territory northeast of Lake Drummond. This area is close to the truck-farming section of Virginia, to which the peat could be cheaply transported by means of the Dismal Swamp Canal. As shown by the table of analyses on page 49, much of this peat is high in thermal value and contains relatively little ash and a fair percentage of nitrogen. It could therefore be used for fuel or as a nitrogenous ingredient of commercial fertilizer.

It is reported that in 1860 a peat-fuel plant was erected near the site of hole A, described below, but that on account of economic conditions which arose with the outbreak of the Civil War it was unsuccessful and the machinery was dismantled. So far as known, this is the only attempt that has ever been made to market peat from the Dismal Swamp.

As shown on Plate IV, test borings for peat were made along the Norfolk & Western Railway, the Dismal Swamp Canal, the canal feeder, and the eastern shore of Lake Drummond. No peat of consequence was found in the region traversed by the railway, but in the other areas the test borings gave the following results:

Hole A was drilled at a point 1 mile north of Wallaceton and 300 feet east of Dismal Swamp Canal. Nonfibrous peat, ranging in color from dark brown to black, was found to a depth of 10 feet. Sample 1 was taken at a point 4 feet from the surface, and sample 2 at 6 feet. (See table of analyses on p. 49.)

Hole B was made on the north bank of Northwest River, 300 feet east of Dismal Swamp Canal. Here 9 feet of peat similar in physical characteristics to the specimens taken from hole A was found. Samples 3 and 4 were taken at depths of 4 and 6 feet, respectively.

Hole C was sunk to a depth of 9 feet at a point midway between the sources of Jericho Canal and of the feeder ditch by which water is supplied to Dismal Swamp Canal. About 8 feet of peat, underlain by white sand, was found here, but as it seemed to be similar to the material from holes A and B no sample was taken for analysis.

Hole D, in which 10 feet of peat underlain by alternate layers of white sand and blue clay was found, was made 200 feet north of the water gate in the Dismal Swamp Canal feeder. The surface layer of this peat is black and well decomposed, but the subsurface layers range in color from dark to light brown. Sample 5 was taken 4 feet below the surface.

Hole E was drilled on the bank of Dismal Swamp Canal opposite the mouth of the feeder. As the peat was rather fibrous and only 3 feet deep at this point it was not sampled for analysis.

NANSEMOND COUNTY.

Hole F was sunk on the south side of Washington Ditch about a mile northwest of Lake Drummond, in Nansemond County. This boring, as well as four others at intervals of three-quarters of a mile northwestward along this ditch, failed to show peat in commercial quantities. From 1 to 3 feet of muck was found, and sample 6, consisting of a composite mixture of material from the surface to a depth of 3 feet, was taken in order to show its character. The absence of peat in this area may be due to the dense stand of mature timber and the excessive quantity of water that cover it, preventing the growth of shrubs, mosses, and other prolific peat-forming plants.

NORTH CAROLINA.

CURRITUCK COUNTY.

Hole J, in Currituck County, N. C., was put down on the north side of Old Swamp Road about 800 yards northeast of the line between Currituck and Camden counties. It penetrated 7 feet of black, thoroughly decomposed peat. The area of this deposit is approximately 100 square miles, and for the most part the material is of the built-up type, though the deposit contains some filled-basin peat. As shown in the table of analyses on page 49, the peat is unusually high in thermal value, contains little ash and a relatively high percentage of nitrogen, and seems to possess much value as a source of fuel and fertilizer.

CAMDEN COUNTY.

Holes G, H, and I, which were sunk half a mile apart along Dismal Swamp Canal, from half a mile to 1½ miles northwest of Lilly, Camden County, N. C., failed to show peat of commercial value. Muck averaging 3 feet in depth was found, but it was not sampled. These tests, however, do not prove that there is no peat in workable quantities in the county. The vegetation in the region consists chiefly of maples, sedges, grasses, canes, ferns, and mosses. Sphagnum moss suitable for surgical dressings is abundant, and it is reported that pure sphagnum covers many square miles in the territory west of Dismal Swamp Canal.

CLASSIFICATION AND PROPERTIES.

PHYSICAL CHARACTER.

The two leading kinds of peat in the Dismal Swamp are known locally as "black-gum peat" and "juniper peat." The former, which is dark brown or black, thoroughly decomposed, and relatively homogeneous in structure, is found in what were formerly the wetter parts of the region, especially near Lake Drummond, and bears a growth of black gum, red maple, and bald cypress. It is well humified and almost destitute of fibrous structure. When dry it breaks easily, leaving lusterless fracture surfaces. "Juniper peat," which ranges from dark to light brown in color and is rather fibrous, is found in the light or open swamp and bears a growth of white cedar, pine, sweet bay, shrubs, and cane. Decomposition is not far advanced and the peat contains many stems, roots, and logs. On the eastern margin of the swamp near the source of Northwest River there is a typical area of this material. When dry it hardens in lump form and breaks with difficulty.

CHEMICAL CHARACTER.

ANALYSES.

The following table shows the results of analyses of Dismal Swamp peats both as received in the laboratory and after the moisture had been eliminated. The samples were dried to about 50 per cent moisture in the field and shipped to the laboratory in canvas bags.

Analyses of specimens of peat and muck from Dismal Swamp, Va. and N. C.

[H. M. Cooper, assistant chemist, Bureau of Mines, analyst.]

Locality.	Sample No.	Hole.	Condition of sample.[a]	Proximate.			Ultimate.			Calorific value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
VIRGINIA.											
Norfolk County....	1	A	1	14.01	45.42	33.92	6.64	0.31	1.73	4,690	8,442
			2	....	52.82	39.46	7.72	.36	2.01	5,454	9,818
Do............	2	A	1	32.93	42.42	19.62	5.03	.23	1.38	3,655	6,578
			2	....	63.25	29.25	7.50	.34	2.06	5,449	9,808
Do............	3	B	1	17.93	46.57	20.15	15.35	.19	1.31	4,052	7,293
			2	....	56.74	24.56	18.70	.23	1.60	4,937	8,886
Do............	4	B	1	18.88	47.55	18.49	15.08	.19	1.27	4,021	7,238
			2	....	58.62	22.79	18.59	.23	1.57	4,957	8,923
Do............	5	D	1	9.38	48.05	18.72	23.85	.28	1.67	3,881	6,985
			2	....	53.02	20.66	26.32	.31	1.84	4,282	7,708
Nansemond County	6	F	1	6.43	30.32	10.92	52.33	.25	1.07	....	....
			2	....	32.40	11.67	55.93	.27	1.14	....	....
NORTH CAROLINA.											
Currituck County..	7	J	1	8.23	52.05	33.54	6.18	.26	1.60	5,163	9,294
			2	....	56.72	36.55	6.73	.28	1.74	5,626	10,127

[a] 1, As received in the laboratory; 2, moisture free.

CONCLUSIONS.

"Black-gum peat" (samples 1, 2, and 5), because of its thorough decomposition, contains more nitrogen and fixed carbon than "juniper peat" (sample 4) and therefore is less acidic. It also contains less ash and is of greater commercial value. Where the ash content exceeds 8 per cent it consists chiefly of alumina and silica in the form of clay and sand.

ASSOCIATED MARL.

Shell beds or so-called marls underlie the peat deposits at many places in nearly all the counties of the Dismal Swamp region. Although no outcropping beds were observed in the areas tested for peat, it is said that many of these strata have been penetrated by wells and extensively exposed by drainage excavations. Shells thrown upon the bank of Dismal Swamp Canal by dredges were seen near Deep Creek and Wallaceton, Va., and Lilly and Moyock, N. C. Several years ago a dredge of the Lake Drummond Canal & Water Co. in deepening the canal feeder penetrated a shell bed about midway between the source and mouth of the feeder. A large quantity of shell "marl" was thrown upon the bank at this point, but on account of the action of the dredge and of the weather since that time it is now disintegrated and mixed with sand and clay. W. C. Mansfield, who identified the following fossils collected at this locality, believes that they are of Pleistocene origin:

Venus mercenaria Linné.
Ostrea virginica Gmelin.
Arca transversa Say.

It has been said[1] that the age represented by these fossils is Pliocene, but as they are also found in the Pleistocene and underlie peat of late Pleistocene origin, it is probable that they belong to the Pleistocene series.

An estimate of the quantity of shell "marl" in the Dismal Swamp region is not available, but if the material occurs in workable quantities and can be cheaply excavated, many peat areas in this region that on account of the acidity of the soil are now valueless for general farming could perhaps be economically treated with lime from these shell beds and made to yield large alkaline-soil crops.

USES.

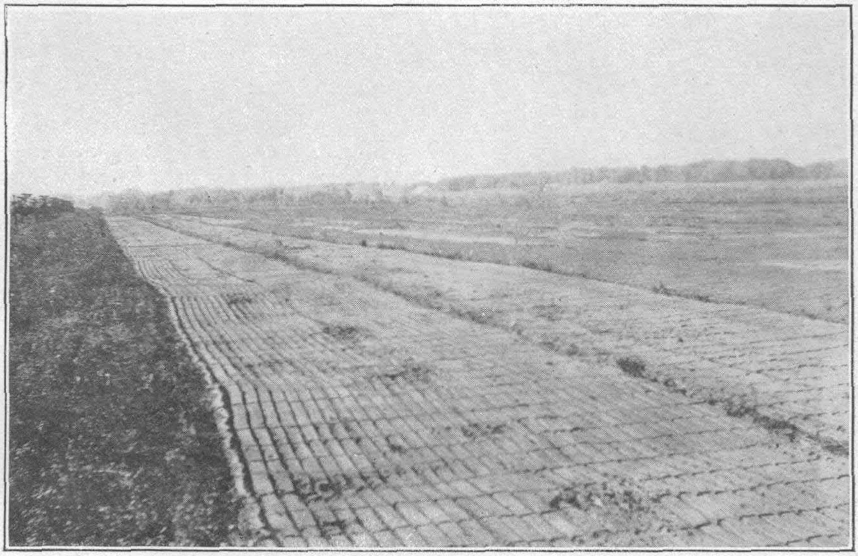
GENERAL USES.

The products that may be made from peat are numerous and varied. In Europe it is shaped into blocks and used for fuel. Gas, charcoal, and coke are also produced from it, as well as ammonium

[1] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), p. 3, 1902.

A. WHEAT GROWN BY THE WALLACE BROTHERS NEAR WALLACETON, VA., ON RECLAIMED PEAT LAND.

Photograph by John G. Wallace.



B. MACHINE PEAT FUEL PREPARED AT THE EXPERIMENTAL PEAT-FUEL PLANT OF THE CANADIAN DEPARTMENT OF MINES, MINES BRANCH, ALFRED, ONTARIO, AND SPREAD FOR AIR DRYING ON THE SURFACE OF THE BOG.

Photograph by E. V. Moore.

COMMERCIAL PRODUCTS OF PEAT.

sulphate and a number of other valuable by-products. Owing to the scarcity of raw material in the countries of northern Europe peat moss is employed as packing material, as a substitute for absorbent cotton in the preparation of surgical dressings, and in a small degree for wood and for cotton and woolen cloth. In the United States peat is used as a soil for the cultivation of certain crops and to some extent for fertilizer, stable litter, and fuel, and for compounding stock feed. It is believed, however, that the greatest possibilities presented by peat in this country are in agriculture and as a source of fuel.

PEAT SOILS.

Peat, when properly treated, is one of the most fertile soil types in this country. In previous years, owing to the abundance of well-drained land that could be more readily tilled, the peat and muck areas have been passed by, but with the rapid increase of our population and the advent of intensive soil cultivation the attention of agriculturists is now being directed to these neglected lands. Raw peat soils, though too acidic for ordinary farming, are, after they have been drained, cleared, and freely aerated, especially well adapted to the production of vetch, buckwheat, oats, rye, some varieties of corn, the cranberry, the strawberry, the blueberry, potatoes, and other acid-soil crops.[1] If properly treated with potash salts and with lime they are neutralized or made slightly alkaline, and should then yield large quantities of red clover, wheat, timothy, alfalfa, sugar beets, rutabagas, and other alkaline-soil crops. (See Pl. VI.) The greatest values derived from the cultivation of peat and muck, however, have arisen from their use as special crop soils. According to the Bureau of Soils,[2] cabbage, onions, celery, lettuce, spinach, carrots, beets, turnips, and peppermint are the most valuable crops that are grown on treated areas of peat and muck. The values of these crops per acre so far surpass those of the general farm crops that the reclamation of any large areas of peat or muck should be undertaken with the special object of their production. For the profitable sale of these special crops it is desirable that such areas of peat and muck as are easily accessible to large city markets or to rapid transportation should be reclaimed first.

The fertility of peat and muck soil is due chiefly to its nitrogen content, to its affinity for moisture, and to its black color, which enables it to absorb heat.

In the Dismal Swamp the areas of black peat land seem to be the most valuable for agriculture. As decomposition is well advanced in these areas the soils contain much nitrogen, are easily worked, and

[1] Coville, F. V., The agricultural utilization of acid lands by means of acid-tolerant crops: U. S. Dept. Agr. Bull. 6, 1913.

[2] U. S. Dept. Agr. Bur. Soils Circ. 65, pp. 13, 14, 1912.

afford a mellow top soil radically different from that of the juniper lands, which cakes and hardens when exposed to the rays of the sun. Because of its pronounced acidity and of its unfavorable physical condition the juniper peat is of little value for general farming unless subjected to intensive treatment. However, frequent plowing, which stimulates the growth of aerobic bacteria, and the application of lime will usually correct these conditions.

On page 50 is mentioned a source from which lime might be economically obtained and applied to this land. Although shell "marl" possesses less value as a fertilizer than commercial lime, it is beneficial to peat soils. Where it has been properly used in Virginia, its application has resulted in increased soil fertility. The shells should be burned or ground before the material is used as fertilizer, because the lime is then available immediately, whereas if the material is applied in an untreated condition the lime is relatively inactive the first year. The chemical and physical effects of liming are manifold: it releases potash from certain silicates; it promotes the decomposition of the peat, freeing soluble nitrogen; it corrects the acidity of sour soils; and peat soils that harden in lumps on drying are made friable by treatment with lime.

PEAT FERTILIZER.

The value of peat as a source of nitrogen for use in the growth of crops seems to have been overlooked by many persons who are interested in the development of a domestic peat industry. Analyses of the peats of the United States show a nitrogen content ranging from 1 to 4 per cent, and averaging about 2 per cent. This nitrogen can be extracted from the peat as a by-product in producer-gas plants or can be made available for plant food without segregating it from the peat. A discussion of the recovery of nitrogen from peat as a by-product in the manufacture of gas is given on pages 58–59.

The use of peat as a culture medium for nitrifying bacteria is now attracting wide attention, and it is believed that this feature of the peat industry offers attractive possibilities. A chemical analysis of raw peat is not a true test of its value as a source of nitrogen for agricultural use, because if the peat is limed and properly inoculated with nitrifying organisms a substantial quantity of soluble nitrogen is gradually formed and released after the peat has been placed on the soil. Arguments are often advanced against the use of peat as a source of nitrogen in soil fertilization because all the nitrogen shown by chemical analysis is not readily available for plant food, but these arguments seem to be based upon a misconception of the nature of peat. It is true that only a part of the actual nitrogen content of peat shown by a chemical analysis can be immediately used for food by plants, but it is equally true that the total quantity of potential soluble nitrogen formed and released by bacterial action from time to time after the peat has been applied to the soil is much greater than the percentage found in some commercial fertilizers. Fortunately not all the nitrogen in peat is soluble, or it would leach out and the black peat soils of this country would be barren.

Peat has been used commercially in the United States in soil fertilization since 1908, having been mixed with potash or phosphate, limed, treated with nitrifying organisms, and applied as a direct fertilizer, or used as a nitrogenous ingredient of commercial fertilizers. For these purposes properly treated peat is valuable both chemically and physically. Its content of soluble nitrogen is immediately available for plant food, and it is potentially rich in nitrogen that is gradually released as needed for plant growth; it contains small quantities of potash and phosphorus; it supplies humus, a vital requirement for plant life under natural conditions of growth; on account of its black color it absorbs heat; soils to which it is applied are made friable and can be readily worked; and its water-holding properties are proverbial. Because of these characteristics peat is being used more and more in the manufacture of commercial fertilizer.

To those who propose to enter this branch of the peat industry it is suggested that caution be observed in selecting a suitable deposit. Before any money is invested a careful survey should be made of the prospective bog to determine whether there is a sufficient quantity of peat to justify the erection of a plant. Typical samples should be taken from different parts of the deposit and examined to determine whether the material is chemically adapted for fertilizer. Black, well-humified peat is most satisfactory for soil fertilization, as such material is generally more compact and contains more nitrogen and less fibrous material than the brown peat. Only bogs containing peat that is rich in nitrogen should be selected. The acidity of the raw peat must be corrected by thorough aeration and liming before any attempt is made to market it. One of the great handicaps suffered by the peat fertilizer industry in this country has been the lack of uniformity in its product, and as the success of a plant depends upon the character of the material used, too much caution can not be observed in selecting it.

Of equal importance to the kind of peat used are the process and machinery employed in refining it. The deposit must first be drained and cleared of trees, brush, and turf. Cultivation of the peat for several seasons will correct the acidity and afford means for determining its general agricultural value. After the upper layer has been plowed, disked, and harrowed, the peat is excavated to a depth of about 3 feet and left in windrows on the surface of the bog. When the moisture has been reduced to about 50 per cent by air drying the material is scraped in piles, loaded in cars, and hauled to the stock pile. After aerobic fermentation is well advanced the material is run through heated rotary dryers until the moisture is lowered to 10 per cent, screened, and cooled. The resulting product contains humus. This material may be further enriched with nitrogen by liming and appropriate inoculation, and if a complete fertilizer is desired, potash, phosphorus, and other minerals are intermixed with it.

The outdoor equipment consists essentially of agricultural implements, excavators, scrapers, loaders, some light rails, a few cars and small locomotives, an elevator to raise the peat to the top of the stock pile, and a conveyor for transporting it to the dryers. If possible the excavators, scrapers, and loaders should be electrically propelled and operated with caterpillar drives, as machinery so equipped gives little trouble on boggy surfaces. The indoor equipment consists of engines, boilers, dynamos, rotary dryers, and sifters. The building containing the drying plant should be fireproof and should be located as near the deposit as possible.

In order that the plant may run throughout the entire year, it is the best practice to excavate and pile up as much peat as possible during the air-drying season and to complete the drying artificially as the material is needed. By adopting the process and equipment described lost motion is minimized and a large proportion of the water in the peat is eliminated in the field.

Farmers who own small bogs can prepare peat fertilizer by composting the raw peat with manure, and after the bacteria have saturated the mixture it may be applied to the soil in the same way as manure. Land that is deficient in humus and nitrogen will thus be materially benefited.

The peat deposits of the Dismal Swamp are within a short distance of many sandy truck farms, to which the peat could be cheaply transported by water, and it seems that peat fertilizer plants in this region should be successful.

PEAT FUEL.

Peat, because its carbon content is higher than that of wood and because it will ignite and burn freely when dry, yielding an intense heat, is used for fuel in countries where the coal supply is below normal requirements. In Ireland peat has been the only domestic fuel of the common people from the traditional time when that country was deforested. It is one of the essential elements of Irish national life, and in many villages remote from modern routes of transportation hand-cut peat is the only fuel available. The peat fire on the hearth, like the jaunting car, typifies Irish environment, and when the tourist seeks a memento of his visit to that country he usually selects some souvenir carved from the black oak that has lain for centuries protected from the attacks of fungi and bacteria by peat.

Although between 15,000,000 and 20,000,000 tons of peat fuel is annually produced in Europe and consumed in generating heat and power, only small quantities of peat fuel have been produced in the United States, because of the abundance in normal times of coal, which is more efficient and could heretofore be more cheaply prepared and more readily transported to the consumer, so that the interest shown in the peat in this country has been largely scientific and experimental. In recent years, however, the increasing cost of producing coal and the temporary failure of the operators to keep pace with the ever-expanding demand have led to a general advance in price. This condition, aggravated by an appreciable reduction in the visible coal supply and the rapid exhaustion of our forests, has made a marked impression upon economists and others and has created a desire to conserve these materials by investigating and substituting other fuels and sources of power wherever they can be more economically used. The late Prof. Van Hise,[1] in urging the conservation of our wood and coal reserves, said:

> So far as practicable other products should be substituted for wood. The original forests of the United States contained not less than 850,000,000 acres, having not less than 4,800,000,000,000 feet of merchantable saw timber. This was our magnificent original heritage. The United States as a nation has existed a century and a quarter, and what have we now? In that brief time approximately one-half of the value of our forests has gone.
>
> So far as practicable substitutes should be used for coal. Even if all possible economies and substitutes are introduced, the most sanguine can not hope that the supply of fuels will be sufficient to meet the needs of the people for more than a small fraction of the time we look forward to as the life of this Nation.

In the northern peat region there are no known coal fields, except in small sections—notably in Michigan—and the peat deposits are confined largely to States which, because of their cold climate and extensive manufacturing industries, consume large quantities of fuel. In the southern part of the coastal region, although the climate is mild and the demand for fuel relatively light compared with that in the Northern States, there are no local sources of high-grade mineral fuels. The preparation of peat fuel from the deposits in these regions would not only increase the local fuel supply but would release railroad cars that are needed for other purposes. Peat therefore has great potential value as a source of heat and power; it may be used locally in some States during economic and industrial crises to prevent a fuel shortage; it may be utilized to conserve our re-

[1] Van Hise, C. R., The conservation of natural resources in the United States, pp. 210, 256, 359, 1910.

sources of coal and wood; and it is thought by many that in some sections remote from the coal fields, notably in New England, peat could successfully compete with other fuels for both domestic and industrial use.

The attempts made in past years in this country to produce peat fuel on a commercial scale have not been successful, but the failure appears to have been due not to a lack of market for the product nor to the lack of merit in peat. In practically every instance it may be accounted for by the lack of sufficient capital, the inexperience of operators, the failure to recognize that peat is inferior to coal, or preventable engineering errors. Many extravagant claims concerning the fuel value of peat have been made, but the sooner its inferiority to coal is recognized the better for the peat industry. Over $1,000,000 has been spent in this country in the attempt to produce some form of peat fuel equal to coal in heating value, and yet we have no large peat-fuel industry.

Careful consideration of all the factors involved leads to the conclusion that peat fuel can now be marketed commercially in the United States only in two forms—air-dried machine blocks and powder. (See Pl. V.) Many attempts have been made both in Europe and in the United States to manufacture peat briquets for commercial use, but, although these briquets are more efficient than machine or powdered peat, the process, on account of the high cost of production, has never advanced beyond the experimental stage. Peat in an undrained bog contains about 90 per cent of water, which must be reduced below 30 per cent before the peat can be used for fuel. By thoroughly draining the deposit approximately 10 per cent of the water contained in the peat may be eliminated, but the remainder, which is held in the microscopic plant cells and minute intercellular spaces, resists the greatest obtainable hydraulic force, and can not be reduced far below 70 per cent without drying in the open air or in a heated chamber. However, artificial drying as a process requires the expenditure of so much heat in comparison with the heat obtainable from the fuel prepared by this method that it has not proved commercially feasible. Peat fuel should therefore be excavated, macerated, and shaped into blocks during the air-drying season, which in the United States begins in April and ends in October, except in the southern peat region, where it is a little longer. As Director Haanel,[1] of the Canadian Commission of Conservation, Mines Branch, has so well put it:

> The forces of nature, the sun and the wind, which cost nothing, should be used, and any improvement in this process will lie in the direction of labor-saving devices.

[1] Haanel, E., Peat as a source of fuel: Canadian Comm. Conservation Ninth Ann. Rept., reprint, p. 16, 1918.

Air-dried machine peat is suitable for both domestic and industrial purposes. In calorific value a ton of machine peat is equal to about 1.3 tons of wood, 0.5 ton of good bituminous coal, and 0.6 ton of anthracite. It is clean to handle and burns freely, yielding an intense heat and producing no soot or other objectionable deposit. For open grates this fuel is nearly ideal, and it is said that peat may be burned in the same stoves as coal and wood. However, the best results in household use could probably be obtained by burning it in a stove with relatively small grate openings and a restricted draft.

The machinery for the manufacture of peat blocks consists essentially of an excavator, macerator, and spreader, which may be separate machines or combined in one. After the peat has been dug it is thoroughly ground into a homogeneous pasty mass and spread from 8 to 12 inches thick on the surface of the bog, and the blocks are marked off by hand as the spreading proceeds. (See Pl. VI.) When partly dry the bricks are loosely stacked in piles. Machine peat that is allowed to dry slowly in this way contracts into a dense mass, covered by a gelatinous skinlike substance called hydrocellulose. After the moisture has been reduced to about 25 per cent this coating renders the peat impervious to water, even when immersed.

Owners of small bogs who desire to prepare peat fuel for home use should adopt the hand-cut process, which is widely used in Ireland. Before this method can be employed the deposit must be thoroughly drained and cleared, and the turf removed from its surface. Most bogs of the built-up type—that is, those which were formed by the deposition of the remains of plants that grow near the ground-water level—can be drained to the bottom by a simple system of surface ditches. Filled basins, in which the deposit has accumulated below a permanent water level, can not generally be drained far below the surface of the peat without incurring great expense and are therefore not so well adapted to hand digging as built-up beds. However, many a filled-basin deposit in the northern peat region, where most of the depressions in which peat has accumulated were formed during the Wisconsin or last glacial stage, may be sufficiently drained for peat recovery by means of a short canal connecting the edge of the basin at the lowest level with an adjacent stream.

After the surface of the bog has been cleared, the peat is dug in brick form, with a special tool, called a "slane." This instrument, which can be made by any blacksmith, is a narrow spade, with a sharp steel lug welded on one side at right angles to the edge of the blade. The blocks of peat range from 8 to 10 inches in length, from 4 to 7 inches in width, and from 3 to 6 inches in thickness, their dimensions depending on the size of the slane. As they are dug they should be removed to the drying grounds and stood on end or placed on covered racks. At the end of about four weeks, during which they should be frequently turned until their moisture content is reduced to about 30 per cent, the blocks are usually ready for storage. As cut peat absorbs water rapidly, great care should always be taken to protect the dry blocks from rain. Peat fuel, prepared in this way, is bulky, is easily crushed, and burns rapidly, with considerable waste. In heating value it is superior to wood, but it is unfitted for commercial use.

For certain commercial uses powdered peat has many advantages over machine peat, as it can be more cheaply prepared and more readily handled. The cheapest way to prepare this product is by the air-drying process, by which the moisture may be reduced to 50 per cent in the field and to about 25 per cent under cover. However, if raw peat is allowed to lie in heaps until natural drainage and evaporation have reduced the moisture content to about 50 per cent, it may be prepared for use under steam boilers by driving off about half of the remaining moisture with waste heat from flues or other sources and pulverizing the resulting material. The powdered peat may then be blown with compressed air into the furnace, where by means of forced draft, ignition is almost instantaneous, and instead of burning on the grate, the peat forms a gas which gives a uniform fire throughout the combustion chamber. Good peat thus treated, when burned in furnaces designed to give the most complete and efficient combustion, will generate nearly as much energy in the form of live steam as the same weight of powdered coal. According to reports in this country, powdered peat has great possibilities, not only for boiler firing, but for metallurgic work and for use in cement and other kinds of kilns in which powdered coal has been successfully burned.

Peat consumed in a properly designed gas producer yields gas of good quality and in abundant quantity in comparison with the yield from coal, and also many valuable by-products. This is, perhaps, the most effective utilization of peat fuel for generating heat and power, because peat that is to be used in this way does not need to be so carefully prepared nor so thoroughly dried as peat that is to be consumed for domestic purposes or under steam boilers.

Analyses of the peats of the United States show that they are rich in combined nitrogen, from 70 to 85 per cent of which—a proportion that in some peats amounts to more than 2 per cent of their dry weight—can be recovered in the form of ammonium sulphate in by-product gas-producing plants. According to the Mond process, which has proved successful abroad, the crushed peat is fed into the furnace of a gas producer, in which combustion is regulated by steam and hot air. The peat burns at the bottom of the feed shaft and, reacting upon the steam, forms water gas and ammonia. These gases are next cleansed of tar by means of a scrubber and are subjected to a fine shower of sulphuric acid, which converts the ammonia into ammonium sulphate and purifies the water gas. After being cooled the water gas may be used under steam boilers, in internal-combustion engines, and for other purposes. It is said that at Cordigoro, Italy, peat containing 2.5 per cent of combined nitrogen, when treated in this way, yielded 170 pounds of ammonium sulphate to the ton. Gas-producing plants using peat fuel have been operated in England, Ireland, Germany, Sweden, Italy, and Russia, but in the United States, although experiments have been made, no such plants are operated with peat.