State of Washington
ALBERT D. ROSELLINI, Governor

Department of Conservation
EARL COE, Director

DIVISION OF MINES AND GEOLOGY
MARSHALL T. HUNTTING, Supervisor

Bulletin No. 44

PEAT RESOURCES OF WASHINGTON

By
GEORGE B. RIGG

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LETTER OF TRANSMITTAL

To His Excellency, Albert D. Rosellini
Governor of the State of Washington

Dear Sir:

I have the honor to submit herewith Washington Division of Mines and Geology Bulletin No. 44, "Peat Resources of Washington," by George B. Rigg.

Washington for many years has been one of the leading states in value of peat production. The wealth of information contained in this report will be found most useful to those who seek peat deposits as sources of material to be excavated for sale. As several farm crops in this state are grown almost exclusively on peat soils, farmers who are interested in growing these, as well as other farm crops, will also find this information of particular value.

It is believed, therefore, that the publication of this report will serve a distinct public need.

Respectfully yours,
EARL COE, Director,
Department of Conservation

June 15, 1958

FOREWORD

For many years the Division of Mines and Geology has received inquiries regarding the availability of peat in Washington. When it was determined in 1949 that a survey of the state's peat resources should be made, the Division was fortunate in obtaining the services of Dr. George B. Rigg, Professor Emeritus, Botany Department, University of Washington. Dr. Rigg is a recognized authority on peat and has spent many years in the study of the deposits of the Northwest. He first began examining sphagnum bogs in Washington in 1909, and between that time and 1949 he had studied some 50 bogs in Washington as well as many in other parts of the country. He had studied the ecology and the physiology of the plants growing on the surface of the bogs and had examined the layers of peat underlying the surface. He was thus the one expert who was most familiar with Washington peat and was best qualified to conduct a survey of the peat resources of the state.

Dr. Rigg was employed by the Division to do the field work on which this report is based, but the results of his many years of past experience are also included in this bulletin, and the many months of work in drawing profiles and writing the report have been contributed by him without pay. Dr. Rigg's valuable contribution will be appreciated not only by those who seek information on peat as a resource to be excavated and marketed but also by agriculturists who are interested in peat lands for growing crops, by botanists, by limnologists, and by students of Pleistocene geology. It is believed that this report will fill a definite need, giving detailed information on a little-known resource that is becoming of increasing commercial value.

MARSHALL T. HUNTTING, Supervisor
Division of Mines and Geology

June 15, 1958

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PEAT RESOURCES OF WASHINGTON

By George B. Rigg

ABSTRACT

Peat deposits are widespread in all but the southeastern quarter of Washington, occurring in 28 of the 39 counties. Most of the deposits are in areas affected by continental glaciation, and 64 percent of the total peat area of the state is in the Puget Sound Basin. Slightly more than 50,000 acres of peat land, including most of the large deposits, was examined. Individual peat deposits vary in size from an acre or less to as much as 3,500 acres, and they vary in depth from a foot or so to as much as 63 feet. There is no consistent relation between large size and great depth. Ten peat areas contain more than 1,000 acres each. Sphagnum bogs are numerous in western Washington, but only a few are found in the eastern part of the state. The largest sphagnum bog is 57 acres in area.

Most of the peat in the state is of the fibrous variety, made up of raw to partly disintegrated and decomposed remains of sedges and other plants. Moss (sphagnum) peat, made up of the remains of moss of the genus *Sphagnum*, usually comprises the uppermost layer in the peat deposits in which it is found. Sedimentary peat accumulates in lakes and is found as the lowermost layer in most peat deposits. It is made up of miscroscopic remains of aquatic plants and of the skeletal remains and feces of small aquatic animals. Woody peat is common also as a minor constituent of some of the deposits. Other less common peats found in the state are salt-marsh peat, hypnum peat, water-lily peat, and equisetum peat. Other materials associated with the peat are muck, marl, diatomite, and pumicite. More than half of the peat deposits contain a layer of pumicite, which in most deposits is ¼ to ½ inch thick but in a few is more than 3 feet thick. Most of this pumicite came from an eruption of Glacier Peak about 6,700 years ago. A few bogs have two layers of pumicite, and two bogs, the Deer Lake No. 2, in Stevens County, and the Fargher Lake deposit, in Clark County, have four layers.

Analyses of 46 samples of peat from 28 different deposits in 14 counties show most of the peat to contain 86 to 95 percent water, 1.5 to 7.5 percent ash, 0.81 to 2.45 percent nitrogen, 0.05 to 0.35 percent P_2O_5, 0.12 to 0.28 percent K_2O, 0.001 to 0.025 percent chlorine, and 0.006 to 0.020 percent sulphur. Acidity varies between pH 3.5 and 7.7, sphagnum peat being the most acid. Most of the peat varies between pH 4.6 and 5.0. Total replaceable bases, expressed as milliequivalents per 100 grams of oven-dry peat, ranges from 1.5 to 116.

Large areas of peat lands in the state are utilized for pasturage and for the growth of crops, considerable amounts of fibrous peat are removed from the deposits and used for soil conditioners, and some peat moss is removed and used as a soil conditioner and for other purposes. Although several other states have much larger acreages of peat lands, Washington has outranked all other states in peat production in the years 1951 through 1954.

CHAPTER I

INTRODUCTION

AIMS AND SCOPE OF THE INVESTIGATION

The primary objective of this investigation was to determine what the peat resources in the state are as to quantity and quality, to what extent they are being utilized, and what further utilization of them can be made. The field work included determining the location, area, and depth of the deposits and the kinds of peat and associated materials that are present in them. Attention was also given to the accessibility, drainage, and clearing of the deposits, and methods of bringing them into condition for agricultural uses. Methods of the removal and processing of peat from the deposits for use as soil conditioners and for other purposes were also considered. Samples of peat for chemical analysis were collected.

The secondary objective was to do as much scientific work on the deposits as possible without regard to immediate application of the results. A considerable amount of information in regard to the origin and course of development of the deposits was obtained. Specimens of *Sphagnum* were collected for determination. Attention was also given to the occurrence of pumicite, diatomite, and marl, and the parts that they may have played in the development of the deposits.

FIELD WORK

Most of the field work was done during the summers of 1949 and 1950, beginning June 15 and ending September 15. Three weeks were spent in the field in 1951, and occasional days in 1952 and 1953. The field party during 1949 and 1950 consisted of George B. Rigg, Special Consultant, State Division of Mines and Geology; Marshall T. Huntting, Geologist in the Division; and an assistant. Coleman S. Leuthy was assistant in 1949 and Frederick A. Nave, in 1950. During 1951 the party consisted of Rigg, Huntting, and Nave. During 1952 and 1953 field work was done by Rigg and Huntting, either together or separately, as occasion arose and opportunity offered.

The field equipment consisted of a New American peat borer, a shovel, an ax, a 100-foot tape measure, a Brunton compass, hand lenses, a set of test papers for determining acidity and alkalinity, and a dropping bottle of dilute hydrochloric acid for testing for marl. The peat borer consists of a brass sampler and 12 threaded steel rods, each 4 feet long and ⅜ inch in diameter, fitted with brass couplings. The sample taken with the borer is approximately 1 foot long and ¾ inch in diameter. The borer, standard equipment for sampling peat deposits, is manufactured by Eberhardt and Sons, Ann Arbor, Michigan. A Hiller borer was also tried. It has the advantage of securing a sample without vertical compression and thus giving exact information in regard to the depth below the surface at which any layer of material is encountered. Its greater weight, however, makes its use laborious, and its calibration in meters instead of feet made it undesirable for this investigation. Several kinds of pH test papers were used, but most of the determinations were made with a set of pHydrion papers, packaged in convenient dispensers, and manufactured by Micro Essential Laboratory, Brooklyn, N. Y. Reference colors are printed on each dispenser. One was a double wide-range roll which indicated whole units of hydrogen ion concentration from 1 to 11. The others were single rolls covering narrower ranges by half units from 3.0 to 8.4.

In the field procedure for each peat deposit the physiographic features, the drainage, the vegetation, and any other data that seemed important were noted, and a line for the profile was selected. This line usually extended from border to border and was so located as to pass through the approximate center of the peat area. In some large areas more than one profile was bored, and in very small ones a single hole was considered sufficient. The distance between holes was chosen mainly on the basis of the size of the area, but in some areas it was varied because local surface conditions indicated that there might be a change in total depth or the thickness of some of the layers. An interval of 100, 200, 300, or 400 feet was commonly used, but in very large areas the interval was 800 feet, and in small areas it was less than 100 feet.

In boring a hole a sod 1 foot deep was removed with the shovel, and the material to that depth was noted. Below that depth each foot was sampled with the peat borer. If gas was evolved, an odor of rotten eggs indicated that it was hydrogen sulphide. If there was no odor, a puff of flame when a lighted match was applied indicated marsh gas (methane). The sample obtained by pushing the open borer down 1 foot was usually less than 1 foot in length because of vertical compression, especially in very wet peat. In some places the peat was so watery that no sample could be obtained. The sample was ejected from the borer onto a piece of newspaper or onto the surface of the ground, and the physical properties were determined. The vegetation at each hole was listed, and the mineral matter under the peat at the bottom of the hole was recorded. In most places the kind of peat could be determined by field examination, and in the few instances in which the peat could not be satisfactorily identified in the field the sample was kept for laboratory examination later. The data from the holes were later used in drawing the profiles and writing the descriptions of the deposits.

FIGURE 1.—Ejecting sample of peat from New American peat borer. Photo by J. C. Sherman.

A map and one or more profiles were drawn for each deposit. Most of the maps were enlarged from county soil maps, but a few were based on aerial photographs, and in some instances sketch maps based on field observation and measurements had to suffice. In the profiles the holes bored are indicated by numbers at the top.

EARLIER WORK

Data on some peat deposits in the state were available from the previous publications of several workers. Dachnowski-Stokes (1930, 1933, 1936) had bored and described a number of deposits. Rigg had bored and described a number of sphagnum bogs, and the papers dealing with these are cited in the literature list at the end of this bulletin. Rigg and Richardson (1934, 1938) had bored and described some sphagnum bogs. Turesson (1916) had bored and described a sphagnum bog. Hansen (1947, and his many papers listed therein) had bored and discussed the sediments (mainly peat) of many deposits in his investigation of fossil pollen in relation to postglacial forest succession, climate, and chronology in the Pacific Northwest. Oswald (1933) had described the vegetation of Pacific Coast bogs. G. M. Valentine, Geologist in the Division of Mines and Geology, had worked on two peat deposits, and his field notes were available. H. E. Sovereign had made a study of diatomite in the state, which included considerable information in regard to the occurrence of diatomite in peat deposits. His report to the State Division of Mines and Mining (1934) was available. G. W. Dorfmeier had made a study of the Lake Leota sphagnum bog in King County, and his typed report was available in the Botany Department at the University of Washington. Information in regard to peat soils was available in the soil surveys of a number of counties. Information in regard to physicochemical conditions in sphagnum bogs had been published by Rigg and coworkers (1916, 1916a, 1927), by Thompson and coworkers (1927), and by Williams and Thompson (1936). Information about interglacial peat had been published by Hansen (1938) and by Hansen and Mackin (1940, 1949). Brief accounts of the peat occurrences in the state were published by Glover (1936) and Valentine (1949).

SOURCES OF INFORMATION ON THE LOCATION OF PEAT DEPOSITS

Information in regard to the location of peat deposits was obtained from many sources. The maps accompanying the U. S. Department of Agriculture Soil Survey reports for a number of counties show the location of most of the deposits. On the earlier maps they are shown as "peat and muck" without distinguishing between the two. On later maps peat and muck are separated, and the various kinds of peat occurring at or near the surface are designated. Topographic maps of the U. S. Geological Survey and the Corps of Engineers, U. S. Army, show many marshy areas, some of which were found to contain peat. Aerial photographs were used to advantage in locating and mapping several deposits. A number of geological papers were helpful in locating peat deposits and interpreting observed geological features. The writer of the present bulletin had worked on sphagnum bogs for about 35 years, and, in addition to his published papers, detailed descriptions of about 40 of these bogs in Washington were available in his notebooks. Also, he had been listing the locations of sphagnum bogs for a number of years, and many persons had contributed information for this list. Much information concerning the location of deposits was obtained by local inquiry.

DEFINITIONS

It seems desirable to define the following terms, which are used frequently in this bulletin.

Bog—A depression or other undrained or poorly drained area containing, or covered with, peat (usually more than one layer) on which characteristic kinds of sedges, reeds, rushes, mosses, and other similar plants grow. In the early stages of development the vegetation is herbaceous and the peat is very wet. In middle stages the dominant vegetation is brush. In mature stages trees are usually the dominant vegetation, and the peat, at least near the surface, may be comparatively dry.

Marsh—A low flat area on which the vegetation consists mainly of herbaceous plants such as cattails, bulrushes, tules, sedges, skunk cabbage, and other aquatic or semiaquatic plants. Shallow water usually stands on a marsh, at least during a considerable part of the year. The surface is commonly soft mud or muck, and no peat is present.

Swamp—A swamp is similar to a marsh except that trees and shrubs comprise the characteristic vegetation. Marshes and swamps merge into each other, and both tend to merge into bogs.

Meadow—A flat area on which the vegetation consists of a dense growth of tall perennial sedges or grasses or similar plants. As used in this bulletin, it includes areas in which the substratum is shallow fibrous peat and on which shallow water stands during at least part of the year.

ACKNOWLEDGMENTS

The generous assistance of many persons has made the work of this investigation easier and the results more valuable. The writer has a deep sense of obligation to all who have helped in so many ways and wishes to express his sincere thanks to all of them.

Mr. Sheldon L. Glover, Supervisor of the State Division of Mines and Geology, made the investigation possible by providing funds, and his counsel and advice have been helpful throughout the investigation. He has read the entire manuscript, and his suggestions have contributed much to the work.

Mr. Marshall T. Huntting, Geologist in the Division, wrote the physiographic descriptions of the counties in chapter IV and gave advice on all descriptions and discussions which involved geology. He drew all but a very few of the maps. He attended to so many details of the work that it would be impossible to enumerate all of them. His resourcefulness and cooperation have solved many problems in the field work, and his industry and enthusiasm have contributed much to the progress and completion of the work.

Mr. Sverre Omdahl, Director of the State Department of Agriculture, granted funds to provide for the chemical analyses. For his interest and cooperation the writer is most grateful.

Dr. L. C. Wheeting, formerly Research Professor of Soils in charge of the Soil Survey at the State College of Washington, permitted the use of soil maps of several counties in advance of their publication, gave valuable information and advice, and extended many courtesies. He also read the manuscript of the chapter on the chemical analyses of peat and gave helpful suggestions.

Dr. Warren A. Starr, who succeeded Dr. Wheeting at the State College of Washington, also permitted the use of soil maps in advance of publication, furnished the descriptions on which the various series of peat soils have been established by the Soil Survey, and extended other courtesies. He also read the manuscript of the chapter on peat analyses and gave helpful suggestions.

Professor D. J. Crowley, Superintendent of the Cranberry-Blueberry Experiment Station operated by the State College of Washington at Long Beach, Pacific County, extended many courtesies during the field work in Pacific County and furnished much useful information in regard to the location of peat areas there and also in regard to the production of cranberries and blueberries on peat soils.

Dr. R. W. Moulton, Executive Officer of the Department of Chemical Engineering at the University of Washington, gave advice in planning the chemical analyses of peat samples and supervised the work of Messrs. John C. Hunt and Lyle J. Gordon in making the analyses in 1949. He also read the chapter on chemical analyses and gave useful suggestions.

Dr. F. J. Goodrich, Dean of the College of Pharmacy and State Chemist at the University of Washington, permitted the use of the laboratory of the State Department of Agriculture for the analysis of the peat samples and also permitted the use of the facilities of this laboratory for the analysis of some samples after the funds that had been provided were exhausted. Assistant State Chemist William Roth made these later analyses.

Dr. R. B. Walker of the Botany Department, University of Washington, read the chapter on the chemical analyses of peat and gave many helpful suggestions.

Dr. S. P. Gessel of the College of Forestry at the University of Washington read the chapter on chemical analyses and made helpful suggestions.

Dr. T. G. Thompson, formerly Director of the Oceanographic Laboratories of the University of Washington, made salinity determinations of brackish water from a lagoon which borders one of the peat deposits.

Dr. R. H. Fleming, Executive Officer of the Department of Oceanography at the University of Washington, and Dr. C. A. Barnes, Associate Professor in the Department, gave valuable information in regard to sea currents along the west coast of Whidbey Island.

Dr. J. C. Sherman of the Department of Geography at the University of Washington furnished maps of some peat deposits on San Juan Island, and he and his students assisted in boring these deposits.

Other members of the faculty of the University of Washington who assisted in various ways are Doctors C. L. Hitchcock (Botany), W. T. Edmondson (Zoology), G .E. Goodspeed, J. H. Mackin, J. D. Barksdale, and Harry Wheeler (Geology), R. J. Robinson (Chemistry), Carl B. Allendoerfer (Mathematics), and Howard R. Gould (Oceanography).

Dr. L. D. Phifer, former member of the staff of the Oceanographic Laboratories of the University of Washington, gave information in regard to peat deposits on San Juan Island and also assisted in boring peat deposits there during the years preceding the present survey.

Dr. A. LeRoy Andrews of Cornell University determined the species of the specimens of *Sphagnum*.

Dr. Guy D. Smith, Director, Soil Survey Investigations, U. S. Soil Conservation Service, gave permission for the use of data determined during field investigations connected with soil survey operations in the state of Washington in July 1956.

Many officials of the Soil Conservation Service, the Forest Service, and also several county agents contributed valuable information in regard to the location of peat deposits.

Cranberry and blueberry producers, officials of logging companies, and farmers also cooperated during the field work.

Acknowledgments of the contributions by the persons who furnished photographs which have been used as illustrations are made in the legends of the illustrations.

CHAPTER II

KINDS OF PEAT AND ASSOCIATED MATERIALS

GENERAL DESCRIPTION

Peat consists of the remains of plants which have accumulated in water or in wet places. The remains and excreta of very small animals, many of them microscopic, may be present, but their contribution to most peat deposits is relatively small. Usually the accumulation requires a rather long period of time, but this varies considerably. Most of the plants whose remains have formed the peat grew where the peat now lies, but some plants or plant remains have been washed in from surrounding slopes. The plants may have been large or small, varying from large trees to microscopic algae and fungi. Shrubs, sedges, reeds, mosses, pondweeds, and other aquatic and semiaquatic plants come between these extremes of size.

The plant remains may have undergone very little change, so that they may be recognized readily with the unaided eye; or they may be disintegrated so that only fragments, rather than whole plants or whole stems, roots, and leaves, are recognizable; or they may be so completely decomposed that their remains can be identified, if at all, only by the use of a microscope. Disintegration is commonly the first change; but disintegration and decomposition go on together, so that the distinction between the two can not always be made in the field examination.

The extent of disintegration and decomposition is often expressed as the degree of humification. A test for determining this is readily made in the field by pressing a convenient quantity of peat in the hand and observing what comes out between the fingers and what remains in the hand. The material which comes out between the fingers may be water or very wet solid material or even slimy semi-solid material. If nothing but water comes out, humification has not begun. The mass which remains in the hand may consist of recognizable leaves, stems, and roots or it may be a formless mass in which no plant remains are recognizable. If all of the material comes out between the fingers and nothing remains in the hand, this indicates that humification is practically complete. Of course there are many stages between these extremes, both as to what comes out between the fingers and what remains in the hand. On the basis of this test, peat is easily recognized as raw, disintegrated, or decomposed. The degree of these changes may be expressed by modifiers such as slightly, somewhat, moderately, or completely. This procedure and ten classes characterizing successive degrees of change based on it were described by von Post (1924), and a translation of this procedure was made by Rigg (1946).

The principal kinds of peat occurring in Washington deposits are moss peat (sphagnum), fibrous peat (mostly sedge), woody peat, and sedimentary peat. Other kinds vary from rather common to occasional to rare. These are hypnum peat, reed peat, tule-reed peat, pondweed peat, water-lily peat, scouring-rush peat, and algal peat. Many mixtures of two or more of these kinds of peat occur. In the present bulletin the term fibrous peat is commonly used to include sedge peat, reed peat, tule-reed peat, water-lily peat, pondweed peat, and scouring-rush peat, because it is not always possible to distinguish these kinds in the field examination and time did not permit extensive laboratory study of samples. Of course, moss peat (sphagnum) is really fibrous in character, but its structure and physical characteristics are so different from other fibrous peats that it can usually be distinguished from them even in the field examination, and it seems best to treat this peat as a separate kind. Hypnum peat is also fibrous, but its physical properties are sufficiently distinctive to justify treating it also as a separate kind. In some deposits there is so little disintegration and decay in reed peat, tule-reed peat, pondweed peat, water-lily peat, and scouring-rush peat that it is possible to recognize these kinds in the field examination, and these terms are used in the descriptions. The sedges (*Carex*) are the most common constituent of fibrous peat, and the terms sedge peat and carex peat are occasionally used where the remains of sedges are readily recognized and no other plants are recognizable. The classifications used by some peat workers in other states differ somewhat from the one classification outlined above and used in the present bulletin, but this classification seems best for use in describing the kinds of peat that occur in the state of Washington.

PEAT

MOSS (SPHAGNUM) PEAT

The structure of the sphagnum mosses is different from that of all other plants. In form they are similar to some other mosses, but in the cellular structure of their leaves, and to a considerable extent in the structure of their stems, they are quite different from all other mosses.

There are 39 species of *Sphagnum* in North America (Andrews, 1913), 24 of which occur in the western part of the continent (Frye, 1918), and at least 12 of which occur in the state of Washington. The various species differ somewhat in form and structure, but all have in common the structural characteristics which set them off distinctly from all other plants. They are of especial interest from both the scientific and the economic viewpoints, and a description of their general appearance, form, structure, and reproduction is desirable.

In the peat deposits of this state the peat mosses are mostly brown, but some of them are reddish-brown, red, green, gray, or even white. Any species may differ somewhat in color under different conditions of light, moisture, and acidity. The individual plants vary from 2 or 3 inches to a foot or more in length. The stems are rather weak, but if they are short they may grow erect. If they grow tall they tend to recline, but they form dense growths and mutual support may keep them erect.

An individual plant consists of a very slender stem, usually not much thicker than a piece of ordinary wrapping twine, and many short leafy branches (fig. 2). The branches are usually in small clusters, and near the apex of the stem they are commonly crowded together so that they give a somewhat headlike appearance to the stem tip. There are leaves on the stem as well as on the branches. The leaves are usually not more than one-fourth of an inch long and are very thin. The plants have no roots, but when young they have small threadlike outgrowths called rhizoids which help in the absorption of water. The stem grows at the tip, and when the base becomes old it dies.

Peat mosses have two means of reproduction—one vegetative and one by the production of spores. New stems may be formed from buds or by renewed growth from some cells of the leaves. New stems may also be formed when branched stems die at the base and branches thus become separated from the stems. The spore reproduction is somewhat complicated, but the organs involved are small and they constitute a negligible part of a mass of moss or moss peat.

The stem in both cross section and lengthwise section shows three distinct regions (fig. 2). The central region is soft and pithlike, being composed of thin-walled cells. Surrounding this is a cylinder of harder tissue somewhat resembling wood. Outside of the woody cylinder there is usually a cortex composed of one to four or more layers of thin-walled cells. When the disintegration of a long-dead stem occurs, this cortex sloughs off and the hard cylinder remains. Hard pieces of these slender cylinders, often 2 inches or more in length, thus are often the most characteristic remains by which sphagnum peat is distinguished, and disintegrated or even partially decayed sphagnum can thus be recognized in field or laboratory examination. Several species of *Sphagnum* (fig. 2) have hyaline cells in the cortex similar to those in the leaves; these cells are described later.

The leaves are composed of a single layer of cells. In the mature leaf these cells are of two kinds—narrow green cells and broader colorless cells (fig. 2). The green cells are so narrow that at first glance under the microscope they may be mistaken for cell walls of the broader colorless cells. The green cells are living, and they perform the work of manufacturing carbohydrates (mainly cellulose and starch) from carbon dioxide and water. The colorless cells are called hyaline cells. In mature leaves they are dead, and when the moss is wet they are filled with water. They have pores in their walls through which water can enter readily, and they are usually reinforced on the inside by ringlike or spiral thickenings (fig. 2) which prevent the cells from collapsing even when subjected to high pressure. More than 100 of these hyaline cells may be present in a single leaf, and there must be several thousand of them in a single plant. The number in a handful of moss must be reckoned in millions, and the total amount of water held in the plants is thus large.

Peat moss as a material is distinguished by its large capacity for taking in and holding water, its resistance to decay, and its acidity. It absorbs large quantities of water in proportion to its dry weight and gives up this water slowly when subjected to moderate drying conditions.

The amount of water taken in and held by peat moss in proportion to its dry weight is much greater than that held by any other plant remains which commonly form peat in Washington deposits. The jellylike layers of sedimentary peat, which show marked colloidal properties, may contain more water in proportion to their dry

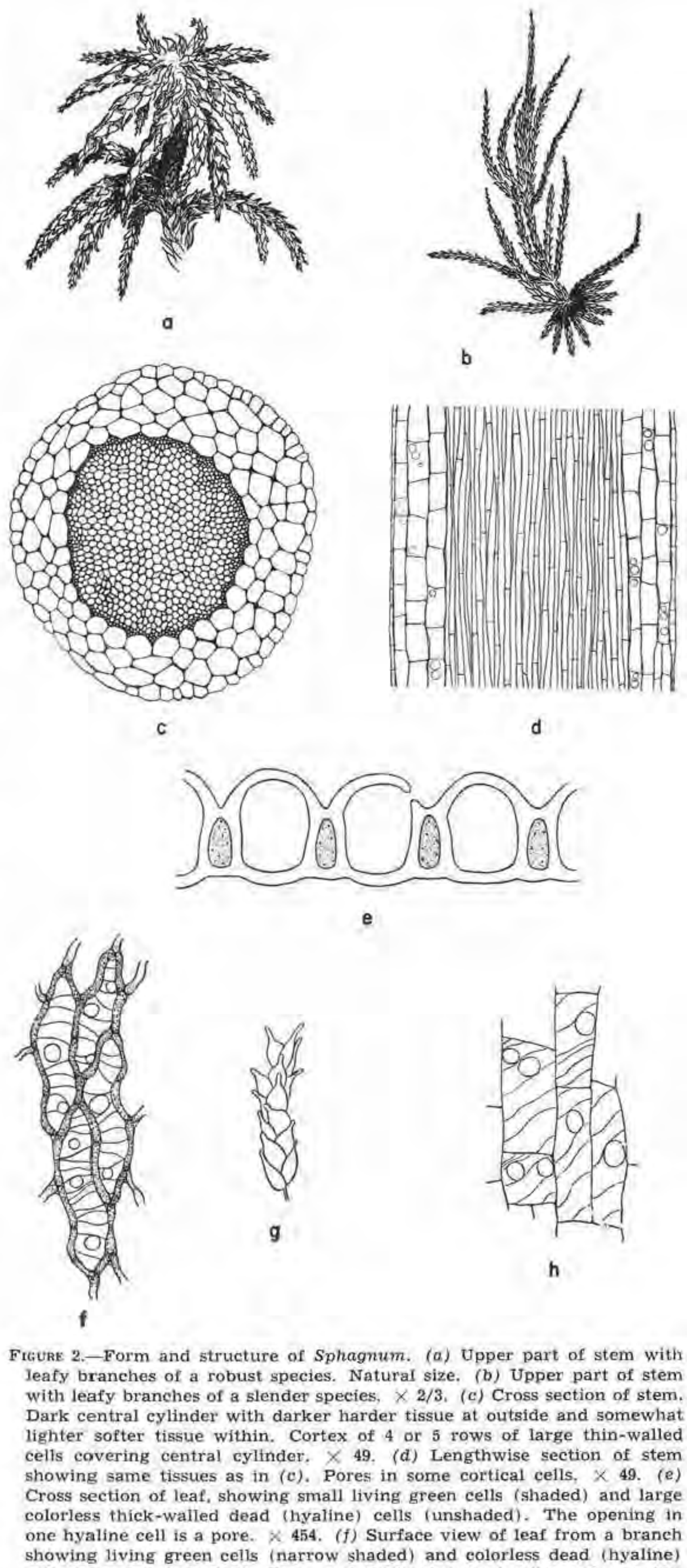


FIGURE 2.—Form and structure of *Sphagnum*. *(a)* Upper part of stem with leafy branches of a robust species. Natural size. *(b)* Upper part of stem with leafy branches of a slender species. × 2/3. *(c)* Cross section of stem. Dark central cylinder with darker harder tissue at outside and somewhat lighter softer tissue within. Cortex of 4 or 5 rows of large thin-walled cells covering central cylinder. × 49. *(d)* Lengthwise section of stem showing same tissues as in *(c)*. Pores in some cortical cells. × 49. *(e)* Cross section of leaf, showing small living green cells (shaded) and large colorless thick-walled dead (hyaline) cells (unshaded). The opening in one hyaline cell is a pore. × 454. *(f)* Surface view of leaf from a branch showing living green cells (narrow shaded) and colorless dead (hyaline) cells (broader unshaded). Pores and thickenings in hyaline cells. × 115. *(g)* A leafy branch. × 3. *(h)* Outer cells of cortex showing pores and spiral thickenings *(c)* to *(h)* are undetermined robust species.

weight than sphagnum peat does, but this sedimentary peat is less common and when exposed to air it rather quickly loses its water by evaporation. The amount of water taken in and held by some species of peat moss is 20 times their dry weight. The minimum water-holding capacity of any species is usually about 10 times its dry weight. The moisture content of peat moss in bales on the market is commonly 30 percent or more.

Water enters a mass of peat moss in three ways; some of it enters the cavities of the hyaline cells through the pores in their walls, some is taken into the substance of the walls themselves, and some is held by capillarity in the spaces among the leaves and stems. The amount of water that goes into the cavities of the hyaline cells is probably larger than that taken in either of the other two ways. The amount that actually goes into the cell walls probably is relatively small, but still it is considerable. It enters by a process called imbibition and actually forces apart the particles of which the walls are composed. This results in swelling of the walls and is comparable to the swelling of cotton fibers when they are placed in water. Imbibed water is difficult to remove by pressure, but it is readily removed by placing the material in warm dry air. The amount of water held by capillarity in the spaces among the leaves and stems is relatively large. It is much more easily removed by pressure than that in the cavities of the hyaline cells and that imbibed in the cell walls. Much of it comes out when the moss is squeezed in the hand.

Peat moss decays more slowly than other plant remains which form peat in Washington. Organisms which cause decay in plant remains are present in peat, but the moss is more resistant to them than other plant remains are. No evidence is available to indicate that the moss kills or even inhibits the growth of organisms; it merely resists them.

Peat moss is acidic. Most of it is strongly so (pH 3.5 to 4.8), but some of it is weakly so (pH 4.9 to 5.5). *Sphagnum* can be grown in water which is neutral in reaction, but it causes the water to become acidic. Even dead spagnum which has been finely ground has the same effect as the living material.

FIBROUS PEAT

Fibrous peat is composed mainly of the remains of sedges (*Carex*) and similar plants. As previously stated, however, the term as used in the present bulletin may in some instances include the remains of other plants such as tules, reeds, pondweeds, and even water lilies and scouring rushes. Some of the sedge fibers are coarse and some are fine, but in either form they are fairly easy to recognize in raw or moderately decomposed fibrous peat in field work. In case of doubt they can be recognized by microscopic examination.

The sedges are grasslike plants. They are herbaceous as distinguished from woody plants. It is easy to confuse them with the grasses. The two are positively distinguished only by technical characteristics, but some readily recognized features serve to distinguish them in most of the species. Most of the sedges have triangular stems, but the grasses have round stems. This difference can be recognized by rolling them between the fingers. A few kinds of sedge having round or nearly round stems do occur, however, in Washington peat deposits. The stems of most grasses are hollow except at the nodes, but the stems of sedges are not hollow. The joints (nodes and internodes) of grasses are more noticeable than those of sedges. This difference usually can be seen in a lengthwise section cut through a node with a pocket knife. The leaves of sedges are usually in three ranks, whereas those of grasses are in two ranks. This can be determined by noting whether two lines down the stem will include the bases of all leaves or whether three lines are necessary. The color of pure fibrous peat is usually some shade of brown.

WOODY PEAT

Woody peat is usually composed of particles of partially decayed wood of pea size or larger, but the size of the particles varies considerably. In peat slime they are very small, and in peat with a relatively low water content there are sometimes found pieces of rotted wood so large that the peat borer cuts sections of them. This latter occurs mostly in mixtures of woody peat with fibrous peat. Many logs in various stages of preservation are found embedded in fibrous peat. In one deposit (Arrow Lake deposit in King County) the logs were so well preserved that they were removed and sawed into rough lumber, which was used in the construction of buildings and other structures used in handling and storing the peat. Logs found in some other deposits are so decayed that they can be penetrated with the peat borer. Woody twigs are common in peat. Where they are abundant and the usual woody particles are absent, the twigs may have originated from shrubs. Leaves of shrubs are also common, and in some deposits layers composed almost entirely of twigs and leaves occur. Such peat is often called heath peat because it originates largely from heath shrubs, of which Labrador tea and bog laurel are examples in this state. Probably some of it in this state originates also from hardhack.

SEDIMENTARY PEAT

Sedimentary peat is deposited in water. It originates from aquatic plants, but in general the remains of these plants have been so completely modified in various ways that they are not recognizable as plant remains even under the microscope. The plants involved are mainly algae, diatoms, and bacteria, but the remains of small slender soft seed-producing plants are also found in some peat deposits. Some of these plants disintegrate and decompose, and their remains at various stages of these processes form peat directly. Others of these plants, especially the microscopic ones, are eaten by aquatic animals. When these animals die, the soft parts of their bodies decay and the products of decay are incorporated in the peat. The feces which the aquatic animals evacuate while they are living are important constituents of sedimentary peat. These visible excreta are commonly in the form of fecal pellets. Some of them as seen under the microscope are rather compact masses with regular surfaces, while others are so soft and have such irregular surfaces that they are mere blobs.

Aquatic animals of various sizes are involved. The very minute ones such as water fleas, water mites, and many others play a very important part. They feed on algae, diatoms, and bacteria, and also on organic detritus of various origins, and the fecal pellets evacuated by them are an important constituent of sedimentary peat. It seems quite probable that some of the fecal matter present in sedimentary peat has passed through the digestive tract of more than one animal, probably first through a larger aquatic animal and then through a minute one.

Kubiena (1953) mentions "excretal remains of aquatic animals", "excretal balls of aquatic animals", "remains of droppings of small animals", and "detritus of droppings of small soil animals", as constituents of peat.

Other objects visible in most peat samples under the microscope are the siliceous remains of diatoms and the chitinous remains of the hard parts of small aquatic animals. The remains of algae are also visible in some samples.

The siliceous remains of diatoms of various sizes and shapes are common in sedimentary peat. Their abundance varies in different deposits and even in different parts of the same deposit. In some samples viewed under the microscope diatoms seem to be a major constituent, but in others very few are present. The line between sedimentary peat and diatomaceous earth is not sharp.

Remains of green or blue-green filamentous or one-celled algae are recognizable under the microscope in some samples of sedimentary peat.

Hard parts of minute aquatic animals are commonly seen in microscopic preparations of sedimentary peat. They are the remains of insects, crustaceans, water fleas, water mites, and other animals. The remains are most commonly fragments of heads, mouth parts, body walls, legs, and egg cases. In some peat samples, however, complete or almost complete organs (e. g., heads) are found. These hard parts are composed largely of chitin—a substance which is resistant to chemical change.

Pure sedimentary peat can usually be recognized in the field by its plasticity and the absence of fibers. A small mass of it can be readily rolled into a ball with the hands. The degree of plasticity can be estimated by flattening the ball by pressure with the finger and observing how readily it cracks at the margin. Sedimentary peat can also be rolled between the hands so that it forms an elongated cylindrical mass which can be held up by one end. Measurements of the length and diameter of such a mass which remains intact when held up by one end are also useful in making a rough comparative estimate of the degree of plasticity and related properties.

An uncertainty in all of these tests is that when the same tests are applied to completely humified fibrous peat the results are similar to those seen when the tests are applied to sedimentary peat. It is very difficult to distinguish sedimentary peat from completely humified fibrous peat by means of field tests. If humification is nearly but not quite complete, some fibers may be found by microscopic examination. In general, diatoms are more abundant in sedimentary peat than in fibrous peat, but this test alone is not a reliable means of distinguishing these two kinds of peat. If a mass of pure sedimentary peat or any completely humified peat is squeezed in the hand it all comes out between the fingers.

The color of sedimentary peat is commonly olive green or olive brown. Some of it is light, and some is dark. In some deposits it is brown or olive brown, and in others it is green or olive green. In a few deposits it is gray.

Sedimentary peat usually shows some colloidal properties. Materials in the colloidal state owe their properties to the extremely minute size of the particles of which they are composed. Waksman (1942), reporting on his work in the peats of New Jersey, discusses peat as a colloidal system and lists the following properties of peat which are characteristic of colloids: (1) the ability to form a stable emulsion with water, (2) the formation of a peat hydrosol from such an emulsion, (3) the swelling properties of peat, (4) the ability of peat to lose water, (5) the buffering properties of peat, (6) the coagulation of peat with bases of heavy metals as well as with salts. Rigg and Thompson (1919) determined the colloidal properties of bog water.

Layers of jellylike sedimentary peat occur in some deposits. The material is extremely soft. It is commonly yellow or tan, but it varies to darker colors. Its origin has not been fully determined, but its properties suggest that it may have been formed by abundant growths of blue-green algae, the cells of which have a thick covering of gelatinous material. This suggestion is tentative, and further chemical and microscopic investigation may demonstrate some other origin.

SALT-MARSH PEAT

Salt-marsh peat occurs along the shores of salt water. It is mostly fibrous, but it consists mainly of the remains of plants that have grown in salt water or brackish water. The fibers may be coarse or fine, and it may be raw, disintegrated, or decomposed. It may be pure, or it may be mixed with clay or silt which has been washed in. Its color is dark brown to light brown to yellow. It has a high content of the salts which are present in sea water. Much of it has an odor of hydrogen sulphide. A familiar way of saying this is that it smells like rotten eggs.

OTHER KINDS OF PEAT

Brief descriptions of other kinds of peat will suffice. Hypnum peat shows some resemblance to sphagnum, but many samples show a reddish color. It is difficult to state properties by which it can be clearly distinguished, but anyone who is familiar with mosses can distinguish it even in the field. Microscopic examination will distinguish it clearly because it does not have the hyaline cells which are characteristic of sphagnum. It consists of the remains of mosses belonging to the genus *Hypnum*, mostly *H. Schreberi* in Washington deposits. Small amounts of the remains of a few other mosses occur with the remains of *Sphagnum* and *Hypnum* in Washington deposits, but they are unimportant.

Water-lily peat can usually be recognized by the remains of the large rhizomes. The large leaf scars are is at hand to indicate whether marl has been formed in Washington lakes by the agency of bacteria.

Small invertebrate animals have contributed to the formation of marl in some of the Washington occurrences. Shells of mussels (pelecypods) and snails (gastropods) are found in marl in some deposits, but they are also found in sedimentary peat where no visible marl is present. No evidence is at hand to indicate to what extent they may have been disintegrated by mechanical or chemical processes to form marl. The evidence for the agency of animals in marl formation in Washington rests on the presence of these shells and the fact that investigators in other states have found such evidence. Data and/or discussion relating to this subject in Michigan are given by C. A. Davis (1900), for New Jersey by Waksman (1943), and for Florida by J. H. Davis (1946). Welch (1935) and Twenhofel (1939) have discussed this subject and cited literature in their textbooks.

Calcium carbonate may, of course, be deposited from its water solution as a result of evaporation, but no evidence has been found to indicate that evaporation has been an important factor in the deposition of marl in Washington peat deposits. Evaporation causes deposition of massive porous calcareous rock (travertine) around some springs and along certain streams, but marl when dry is in a powdery or slightly consolidated condition, quite distinct from travertine. No travertine has been found in Washington peat deposits.

DIATOMITE

Diatomite consists of the powdery siliceous remains of diatoms. It is also called diatomaceous earth, but for relatively pure deposits the name diatomite is preferable. Pure diatomite is white, and this is the color of most of the widespread thick deposits that are interbedded with Miocene basalt in Kittitas, Yakima, Franklin, Benton, and Grant Counties. These deposits of fossil diatoms will not be considered here but are described in other reports (Glover, 1936, p. 38-42; Skinner and others, 1944, p. 20-32; Mackin, 1956; Valentine, 1949, p. 29-30).

Although the pure material is white, most diatomite in Washington peat deposits has a grayish color. Some of it is tan, and some is umbrous. In layers in which it is mixed with peat the colors are dark gray, brown, and dark brown. Most of it is very slightly consolidated, but in some deposits it is too compact to be penetrated with the peat borer. In the field it cannot be distinguished with certainty by its color alone from pumicite and marl, but it can be distinguished by other tests. When rubbed between the thumb and finger it has a smooth feel, whereas pumicite has a slightly gritty feel. It can be distinguished from marl by applying a drop or two of hydrochloric acid. Marl evolves bubbles of gas in this test but diatomite does not. In the laboratory, diatomite can be distinguised by microscopic examination, as the tests of diatoms—either whole or broken—can be readily recognized.

Diatoms are microscopic plants which grow in enormous numbers in both fresh and salt water and are also found in soils. Each individual consists of a single cell whose wall (test, envelope, frustule, shell) is composed of silica. These walls, which remain after the interior living part has died, may accumulate to form thick deposits. The wall is composed of two parts which overlap somewhat as do the two parts of a small paper box. Diatoms reproduce rapidly by cell division and also by complicated sexual processes. Both kinds of reproduction involve the separation of the two halves of the test. The tests are beautifully sculptured, and the variety in patterns, when considered in connection with the size and shape of the individuals, enables the observer to distinguish diatoms from other organisms and also from particles of non-living matter. These same characteristics are the main basis for classification of diatoms into more than 8,000 species belonging to many genera. Living diatoms have a brown color which masks the green color of their chlorophyll.

Diatoms are common and abundant in Washington lakes. They occur free in the open water of the deeper parts of the lakes and also in the shallow water of the margins. Colonies of some species grow on other plants in the shallower parts of lakes, and these and free individuals are numerous in the organic matter that accumulates on the leaves and stems of plants and also on dead twigs and other objects in shallow lake margins.

Scheffer and Robinson (1939) found 14 species belonging to 8 genera in the open water of Lake Washington near Seattle and also 35 forms belonging to 16 genera in the shallow water of the margin of the lake. Kemmerer, Bovard, and Boorman (1923) found them in greater or less abundance in a number of lakes in both eastern and western Washington. The investigations by Sovereign of the diatomite in the Clover Creek (Parkland) peat deposit in Pierce County are reported in chapter IV. Davis (1900) found that the silica present with the calcium carbonate encrustation on *Chara* in a Michigan lake consisted largely of the tests of diatoms.

Diatoms are present in the peat in many deposits in Washington. Dorfmeier (unpublished manuscript, Botany Department, University of Washington) found a pocket of diatomaceous earth near the margin of the Lake Leota peat deposit near Seattle. The percent of mineral matter (mostly tests of diatoms) in a sample dried to constant weight was 59.58. He found 50 species of diatoms belonging to 14 genera in the diatomaceous earth. All of the genera were also found in the peat of this deposit. The tests of many of the diatoms were broken. The species were determined by Mrs. H. E. Sovereign. Dachnowski-Stokes (1930, 1933, and unpublished field notes) found diatomaceous peat in a number of deposits in western Washington and some in eastern Washington. In the field investigation of peat on which the present bulletin is based, the physical properties of many peat samples indicated the presence of large quantities of diatom tests.

Diatomite is common in peat deposits in Washington. The deposits examined in the western part of the state in which it is most abundant are Clover Creek deposit near Parkland (fig. 144) and Harts Lake deposit (fig. 150) in Pierce County, Shadow Lake deposit (fig. 46) and Panther Lake deposit (fig. 58) in King County, and Black River deposit (fig. 226) in Thurston County. Smaller rence of some condition that will cause its precipitation. The calcium in solution in the waters of lakes is in the form of calcium bicarbonate and is precipitated as calcium monocarbonate. It seems evident that in Washington most of the calcium which is finally precipitated as marl is brought into the lakes by streams from neighboring regions, mostly mountains, but possibly some is dissolved from the glacial drift in which the lakes occur.

The origin of the calcium in the deposits in the Deep Creek-Cedar Lake region in Stevens County merits special attention because the total amount of marl deposited in peat deposits there is larger than in any other region of the state. This is a narrow flat-floored valley into which mountain streams from both sides have built alluvial fans. Carbonate rocks are abundant in the region, and it seems evident that much calcium along with other mineral material has been brought in by these streams. It is impossible to say to what extent calcium in the other deposits in Stevens and Spokane Counties was brought in by streams or derived from nearby rocks or from glacial drift. The marl deposits in Ferry County and those near Riverside, Okanogan County, are in areas where limestone crops out. In Whatcom County, calcium is evidently brought in by the Nooksack River drainage from the Mount Baker region, and possibly some is derived from glacial drift. In the Campbell Lake deposit, calcium may have come from local limestone deposits or from glacial drift.

The main cause of the precipitation of marl is the decrease in the concentration of carbon dioxide in the water. The principal cause of this decrease commonly is the use of carbon dioxide by green plants (algae and rooted plants) in the process of photosynthesis. Calcium bicarbonate is soluble in water, but calcium monocarbonate is practically insoluble. The withdrawal of carbon dioxide results in a change of the bicarbonate to the monocarbonate, and it is thus precipitated as marl. The equation $Ca(HCO_3)_2 \rightleftharpoons CaCO_3 + H_2CO_3 \rightleftharpoons H_2O + CO_2$ represents this reaction. This is a well-known reversible reaction. It is evident that withdrawal of carbon dioxide will cause the reaction to go to the right and thus result in the deposition of calcium carbonate, while addition of carbon dioxide will cause the reaction to go to the left and thus keep the calcium in solution.

The amount of carbon dioxide in the water may also be decreased by a rise in temperature, because it is less soluble in warm water than in cold water. Carbon dioxide will thus be lost to the atmosphere. The concentration of carbon dioxide in a lake is always tending to come into equilibrium with its concentration in the air which is in contact with the water. The amount of carbon dioxide lost by increase in temperature may under some conditions be greater than that withdrawn by photosynthesis, and temperature change may thus become the principal factor in marl formation. This means that the presence of a layer of marl may be evidence of temperature changes in the region in past times. The beginning of marl formation may mark the beginning of a warmer period, and the end of marl formation may mark the beginning of a colder period, while the continuance of marl formation may indicate stable temperature. This, of course, assumes the continued presence of a sufficient supply of calcium in the water. If this supply is exhausted or becomes unavailable, marl formation will cease regardless of the abundance or scarcity of carbon dioxide. The supply of calcium may fail because it is all used up or, if it is derived from glacial drift, its diffusion into the water of the lake may be prevented by the deposition of a layer of organic matter. Deevy (1953), citing publications by workers in both Europe and America, has summarized and interpreted the evidence that the deposition of calcium carbonate may be evidence of climatic change. Whether this may be true in Washington deposits of marl is an open question.

The plants whose photosynthesis is the main factor in the development of marl deposits in Washington are evidently *Chara*, some aquatic seed plants, and blue-green algae. Much evidence that these plants play important roles in other states has been published, and their presence in places where marl has formed in this state is the basis of the inference that they are also important here.

Chara is probably the most important. It is a very slender plant, usually classified with the algae, which has numerous whorled branches and often reaches a length of 1 foot or more. It is abundant in most of the lakes where marl has been deposited. The plant flourishes in water which is approximately neutral, and encrusts itself with a heavy calcareous coating. Its abundance, its vigorous growth, and its large exposure of surface in proportion to its bulk may be factors in its success as a marl former. Possibly some peculiarity of its metabolism is also a factor. Evidence for its role in marl formation in other states has been presented and discussed by many workers (Davis, 1900; Rickett, 1924; Twenhofel, 1939; and others).

Lime-encrusted seed plants have been found in Washington lakes in which marl occurs, but no systematic list of them has been made. Data on aquatic seed plants as agents in marl formation in other states and in Canada have been published by Davis (1900), Welch (1935), Kindle (1927), and others. Among the plants listed are water weed (*Elodea*), pondweed (*Potamogeton*), hornwort (*Ceratophyllum*), water lily (*Castalia*). All of these occur in Washington lakes.

Blue-green algae are common and abundant on the muddy, peaty margins of Washington lakes in which marl occurs, and green algae also occur. Among the workers who have investigated blue-green algae as agents in marl formation are Davis (1900), Pollock (1918), and Kindle (1927). These plants often form pebble marl, which may eventually lose its pebble form. Welch's textbook on limnology (1935) discusses algae as agents in marl formation.

It seems probable that bacteria are either direct or indirect agents in the precipitation of calcium carbonate in lakes in various parts of America. Williams and McCoy (1934) worked on a Wisconsin lake, and Twenhofel (1939) discusses their work and also the work of others. Deevy (1953) says that the role of bacteria in calcium precipitation is apparently minor, though variable. No evidence

MUCK

Muck is common in and around peat deposits in Washington. It is most frequently found on the borders of the deposits, but a layer of it may occur at the bottom of the deposit, and one or more layers may occur at various depths in the deposit.

Muck is distinguished from peat on the basis of the degree of decomposition of the plant remains from which it originated (Soil Survey staff, 1950). If decomposition has gone so far that recognition of plant remains is impossible, the material is regarded as muck; if plant remains are still recognizable as such, it is regarded as peat. Peat is regarded as the parent material from which muck originates. If plant remains accumulate more rapidly than they decompose, peat is formed. If, however, they decay as rapidly as they grow and die, muck may be formed without any perceptible peat stage.

Though the percent of mineral matter in muck is commonly larger than it is in peat, the mineral content is not a dependable basis for distinguishing muck from peat.

Some sources of the mineral matter which commonly accumulates in muck are evident. As the plant materials decompose, the mineral matter that was in them remains in the resulting muck. Mineral matter may be washed into the mass of decomposing plant remains by drainage from the surrounding slopes, or it may fall from the atmosphere in the form of dust or other finely divided particles.

In the examination of organic materials in the field during the peat investigation it has usually been possible to distinguish muck from peat. In some instances, however, field characteristics were not a reliable basis for distinction. Microscopic examination is necessary in order to determine whether any plant parts (often partially or wholly disintegrated) are present.

The soil surveys, cited earlier in this chapter, report investigations of the relation of types of peat to types of muck, and L. C. Wheeting has also furnished information on these relationships to the State Division of Mines and Geology. On decomposition, Mukilteo peat goes to Semiahmoo muck, and Rifle peat to Carbondale muck. Greenwood peat has no muck counterpart.

MINERAL MATTER

In addition to the organic material discussed above, mineral materials also occur in peat deposits. Marl, diatomite, and pumicite (volcanic ash) are the most common, but bog iron is occasionally found. Clay and sand occur as separate layers and as mixtures with peat.

MARL

Marl occurs in peat deposits in northeastern and northwestern Washington. It is a powdery to fine-granular material that commonly resembles unconsolidated chalk. In composition it is mainly calcium carbonate, but other minerals may be present. Wilson and Skinner (1937), have given the following composition of marl in the Booher pit in Okanogan County:

Calcium carbonate	94.3 percent
Magnesium carbonate	2.1 percent
Free silica	1.3 percent
Iron oxide	0.12 percent

Pure dry marl is white, and in some Washington peat deposits it shows this color, but most of it is either cream colored or tan. Other colors observed are gray, greenish gray, yellow, yellow green, green, yellow brown, and light brown. These colors are probably due to the presence of substances other than calcium carbonate. The grayish colors may be due to the presence of clay. The brownish colors probably indicate the presence of peat or other organic matter or of iron oxide. The greenish colors are probably due to a content of ferrous iron or the presence of chlorophyll which has remained stable at low temperatures in the absence of oxygen and light. The yellow colors might be due to carotene or related compounds or to ferric iron.

The marl-containing peat deposits in the northeastern part of the state are in Stevens (figs. 216, 219, and 223), Spokane (figs. 210, 211, and 213), and Ferry Counties. Those in the northwestern part of the state are in Whatcom (figs. 248, 249, and 255), and Skagit (figs. 169 and 172), and King (fig. 45) Counties. They are most numerous, deep, and extensive in Stevens County. In one deposit there (fig. 216) the maximum thickness of the marl layer is 25 feet, and marl extends 1,070 feet along the profile. In one of the deposits in Spokane County (fig. 213) the maximum thickness of the marl layer is 17 feet, and marl extends 355 feet along the profile and also into the lake. The three deposits known in bogs in Ferry County are relatively small.

In Whatcom County, layers of pure marl in peat deposits are relatively thin, but in some deposits thicker layers of marl mixed with other materials occur. In one deposit in the Wiser Lake area (fig. 249) the maximum thickness of the marl layer is 2 feet, and it extends 1,300 feet along the profile. In the Fazon Lake deposit (fig. 255) the marl is mixed with sedimentary peat, fibrous peat, sand, and clay. The maximum thickness of this mixed layer is 7½ feet, and it extends 900 feet along the profile. Only one marl deposit of appreciable size has been found in Skagit County (fig. 172), and in it there are two layers of relatively pure marl, and there is also some marl mixed with sedimentary peat. Marl occurs in the Covington deposit in King County (fig. 45).

The occurrence of marl in Washington is not confined to peat deposits. In the eastern part of the state it occurs in several deposits now out of water and not associated with peat (Valentine, 1949, p. 51). The largest of these, the Booher pit, near Riverside in Okanogan County, is 25 feet deep and has an area of 50 acres. It has been described by Wilson and Skinner (1937). In 1951 marl was being dug from it and processed for sale for soil conditioning. Marl in small to large quantities also occurs under water, as in White Mud Lake near Colville in Stevens County, in a small lake near Van Zandt in Whatcom County, and in other places in Washington.

Obviously, the deposition of marl requires the presence of calcium in solution in the water and the occur-usually visible even when disintegration and decay are nearly complete.

Equisetum peat can be recognized by the remains of the jointed, longitudinally fluted stems and the harsh feel of the remains.

The remains of reeds, rushes, and tules sometimes form matted layers in peat deposits. They can be recognized by persons familiar with these plants, but it is difficult to state exact characteristics by which they can be distinguished clearly in field work.

RATES OF ACCUMULATION OF PEAT

Average rates of accumulation in 151 deposits in the Puget Sound lowlands have been computed (Rigg and Gould, 1957). The data used in each computation were the depth of the peat and the time elapsed during its accumulation. The three depths used were the total depth of the deposit, the thickness of the layers of peat overlying the layer of pumicite (volcanic ash), and the thickness of the layer of peat underlying it. Data on these depths were available for all 151 deposits. Data in regard to elapsed time were the approximate dates of the beginning of peat accumulation in three deposits and the date of deposition of the layer of pumicite in two deposits.

The average rates, expressed as number of years elapsed during the accumulation of 1 inch of peat (with depth in feet in parentheses) are as follows:

Average for total depth (24 feet)	41 years per inch.
Average for depths above pumicite (14.6 feet)	39.6 years per inch.
Average for depths below pumicite (9.9 feet)	43 years per inch.

The dates used in the computations were determined by radiocarbon dating. The determinations were made at the Lamont Geological Observatory on samples which had been taken from deposits in Washington. Those samples for the determination of the approximate date of the beginning of peat accumulation were taken from the very bottom of the sedimentary peat where it was in contact with blue clay. One was taken from the Covington deposit, one from the Moss Lake deposit, and one from the peat accumulated in the bottom of Lake Washington in King County. These dates are respectively 10,200 ± 500 years, 11,900 ± 360 years, and 13,650 ± 550 years ago. The average date of 11,900 years ago was used in the computations.

The samples of peat used in the determination of the date of the deposition of the pumicite were taken just under the pumicite layer.

The two deposits in which the date was determined are Covington and Moss Lake, both in King County. In the Covington deposit the date (years ago) is 6,500 ± 200 years, and in the Moss Lake deposit it is 6,950 ± 200 years. The average date of 6,700 years ago was used in the computations.

In addition to the computations on these 151 deposits, some computations have been made on 55 other deposits. Some of these are in eastern and northeastern Washington, some are in Idaho, and some are in British Columbia. The average depth of peat above the layer of pumicite in these deposits is 11.5 feet, and the average rate of accumulation is 48.5 years per inch. The rate of accumulation below the pumicite could not be computed, because the date at which the accumulation of peat began in these deposits has not been determined.

Comparisons have also been made of the rates of accumulation of two kinds of peat. The kinds are limnic (sedimentary) and fibrous, which in this comparison includes sphagnum peat. Taking all available data into consideration, it seems evident that the average rate of accumulation of these two kinds of peat has been approximately the same.

PEAT SOILS

The various types of peat soil occurring in the state have been described in the soil surveys of several counties. Among these are Snohomish (Anderson and others, 1947), King (Poulson and others, 1952), Kitsap (Wildermuth and others, 1939), and Clallam (Smith and others, 1951). Muck and peat have been discussed in the soil surveys of Spokane and Stevens Counties and in other publications. Up-to-date descriptions of the types of peat soils have also been furnished to the State Division of Mines and Geology by Warren A. Starr of the Washington Agricultural Experiment Station at the State College of Washington.

The following is a brief characterization of these types. The author of the present bulletin assumes full responsibility for any failure of these brief statements to characterize these types exactly.

Greenwood peat consists of the remains of mosses, largely *Sphagnum*.

Mukilteo peat is composed of remains of various sedges and associated water-tolerant plants, but includes considerable amounts of colloidal, woody, and mineral materials.

Spalding peat, in its upper layer of about 8 inches, is medium to dark brown and is derived mainly from sedges, reeds, and other marsh plants. It contains much fine organic material that imparts a very smooth feel when moist, but is spongy and matted when dry. Below the upper layer the material is lighter brown and becomes more raw, fibrous, and spongy with increase in depth.

Rifle peat is an accumulation of woody plant remains that are in various stages of decomposition, but in which there still remain many recognizable woody fragments.

Tanwax peat is developed from microscopic plants and fine colloidal sediments accumulated in glacial lakes and other ponded-water depressions under conditions of poorly developed drainage and cool climate.

The above descriptions, of course, are of soil types. The maximum depth mentioned in the original descriptions is 51 inches. The kinds of peat described in the present bulletin include all materials down to the mineral layer in all deposits in which it could be reached by use of the peat borer. The maximum depth reached was 63 feet. In general, Greenwood peat of the soil surveys corresponds to moss (sphagnum) peat of the present bulletin; Mukilteo and Spalding peat, to fibrous peat; Rifle peat, to woody peat; and Tanwax, to sedimentary peat.

amounts are present in deposits in Clark, Kitsap, Mason, Snohomish, and Whatcom Counties. In eastern Washington the largest amount is in Deer Lake peat area No. 1 (fig. 221) in Stevens County. Smaller amounts are present in Chelan, Ferry, Grant, Lincoln, Pend Oreille, and Spokane Counties.

Layers of diatomite show great variation in their thickness, their depth below the surface, their purity, and their associated sediments. They occur at any depth from the surface to the bottom of the deposit. The thickness of layers may vary from a few inches to 4 feet or more. The diatomite may be relatively pure, or it may be mixed with peat or muck. The layers may be in contact with muck, fibrous peat, pumicite, or other materials.

The reasons for the occurrence of diatomite in the various positions is not fully known. Several factors influence the rate of growth and reproduction of diatoms in lakes, and it is not always evident which factor is the limiting one. The most obvious factors are light, temperature, and the presence of gases and nutrients. The light intensity may have varied with climatic changes, or it may have been limited in some parts of the lake because of the turbidity of the water. This turbidity may have been due to the presence of living organisms or their remains or to silt or other mineral matter in suspension in the water. The temperature of the water may have varied with climatic changes or it may have been different in different parts of the lake due to springs or the inflow of surface water. The most important gases are oxygen and carbon dioxide. Photosynthesis and respiration of the diatoms themselves and other chlorophyll-containing plants influence the concentration of both of these gases, and the respiration of all living organisms, both plant and animal, is also a factor.

The concentration of nutrient salts such as phosphates and nitrates may vary from one lake to another or from time to time in the same lake. The supply of the silica which is necessary for the formation of the walls of diatoms may vary with time and place. It is possible that the abundance of diatoms may be influenced by the abundance of silica dissolved from layers of pumicite. It must be remembered also that the requirements of some species of diatoms as to light, temperature, and nutrients are very different from those of others. The available data on the growth of diatoms in Washington lakes are not sufficient to justify any specific conclusions as to what may have caused their greater abundance at any specific time and place. The data do, however, furnish a basis for interesting speculations. One of these is whether the deposition of a layer of pumicite is the determining factor in the greater abundance of diatoms soon afterward.

PUMICITE

Pumicite (volcanic ash, volcanic dust, volcanic glass) is ejected from volcanoes during violent eruptions. Pumice is usually ejected at the same time, but it is in larger particles (pea size, popped-corn size or larger), which float on water for a time, whereas most pumicite sinks relatively soon. The pumicite deposits of the state which reach thicknesses of 40 feet or more and which have value for commercial uses are not associated with peat deposits and will not be considered in this report. They have been reported previously (Glover, 1936, p. 88-90; Carithers, 1946, p. 56-78; Valentine, 1949, p. 72). In Washington peat deposits, pumicite is usually white or some shade of gray, but in some layers it is tan, umbrous, or brown. The darker colors may be due to oxidation of iron or other impurities after deposition, or possibly the material may have had a darker color when it was ejected.

It consists of small particles which vary in size but are usually less than one twenty-fifth of an inch in their greatest dimension. They can usually be seen with the unaided eye and are plainly visible under an ordinary reading glass. Different sizes occur, sometimes in the same eruption, and sometimes in separate eruptions in the same region. The eruption of Mount Katmai in Alaska in 1912 deposited two layers differing in size and color but merging into each other. In the Fargher Lake peat deposit in Clark County (fig. 10) the pumicite in one layer is so coarse (sand size) that it might be regarded as fine pumice, but in other layers it is fine to powdery.

The particles of pumicite are mostly irregular in shape and sharply angled. Much of the pumicite is essentially like powdered glass. For this reason the material feels somewhat harsh when rubbed between the fingers. Thus in the field it usually can be distinguished from diatomite, which feels smooth. Microscopic examination may be necessary for positive identification, however. The particles consist mainly (70 percent or more) of silica, but alumina (up to 14 percent) is present, and magnesia, potash, soda, lime, and iron oxide normally occur in smaller quantities.

In Washington deposits the pumicite is usually loose enough to be easily penetrated with the peat borer, though it is distinctly harder than the peat immediately above or below it. Because of this relative hardness, a layer of pumicite can usually be located with the peat borer without taking samples from the surface down to it. In some deeper layers (e. g., part of the Saltese Marsh deposit in Spokane County, fig. 205) it is too compact to be penetrated completely with the peat borer, and there the thickness of the layer and the nature of the underlying material have not been determined.

Pumicite occurs in most of the peat deposits in both western and eastern Washington. Usually there is only one layer in a deposit, but in some deposits there are two or more. In the Fargher Lake deposit (fig. 10) in Clark County and in the Deer Lake No. 2 deposit (fig. 222) in Stevens County four layers occur. In deposits in the western part of the state the layer is commonly 1 inch or less in thickness, but in some places it is 2 inches or slightly more. Layers varying from ½ inch to 2 inches in thickness occur in the Carpenter Lake deposit (fig. 80) and the Gurley Creek deposit (fig. 89) in Kitsap County; the Clover Creek deposit (fig. 144) and the Silver Lake deposit (fig. 141) in Pierce County; the Phantom Lake deposit (fig. 40) and the Covington deposit (fig. 45) in King County; and in many other deposits.

In the eastern part of the state there are some thin layers (e. g., the Lost Creek deposit [fig. 136] in Pend

Oreille County), but most of the pumicite is much thicker (up to 3 feet) in at least part of the layer. Examples are the layers in the Saltese Marsh deposit (fig. 205) and the Lakeside Marsh deposit (fig. 210), and the deeper layer in the Newman Lake deposits (figs. 206 and 207), in Spokane County; the Loon Lake deposit (fig. 224) and the Deer Lake deposits (figs. 221 and 222) in Stevens County; the Davis Lake deposits (figs. 127 and 128) and the Rufus Meadow deposit (fig. 135) in Pend Oreille County; and the Bonaparte Meadow deposit (fig. 117) in Okanogan County.

The pumicite which occurs in thin layers of fairly uniform thickness evidently in most places fell on the surface of lakes in which some peat had already been deposited. As it sank to the bottom it thus marked the upper surface of the peat deposit as it was at that time. Where it is in thick layers, some of it undoubtedly fell on the surface of the lake but most of it was probably washed in from surrounding slopes. This interpretation is supported by three lines of evidence: (1) In many deposits (e. g., the Bonaparte Meadow deposit [profile B, fig. 117] in Okanogan County and the Diamond Lake deposit [fig. 124] in Pend Oreille County) the layer is thick at the margin of the deposit and gradually thins out toward the center. This, however, is not true in all deposits, as in the Davis Lake deposit (fig. 128) in Pend Oreille County the layer is thick at the center; here, the sides of the deposit are steep and the ash could naturally slide from the edges toward the center. (2) No geologically recent volcanic eruptions of magnitude sufficient to deposit directly such thick layers of pumicite as occur in some peat deposits of eastern Washington are known. (3) Observations made by Rigg on Kodiak Island in Alaska in 1913, one year after the eruption of Mount Katmai, indicate that large quantities of pumicite are washed down steep slopes after a volcanic eruption of the explosive type. The ash was 11 inches deep on flat land near the village of Kodiak. Ash had washed down the mountain side in such quantities that it had moved a house from its foundation, and at Kalsin Bay it had completely filled the margin of the lake and had ruined it as a source of water for cattle at the Agricultural Experiment Station.

Consideration must also be given to the direction and force of the wind at the time the shower of pumicite settled on the lake surface. Pumicite may float for a short period, and if the wind is strong the floating pumicite may drift to one side of the lake. Some hillside deposits of pumicite along the valley of the Snake River and its tributaries were apparently deposited in this way, and probably some pumicite in one side of peat deposits may have been deposited in the same way. The layer of pumicite is much thicker at one end of the profile than at the other end or in the middle in the deposit at the south end of Newman Lake in Spokane County (fig. 206), also in profile C in Cedar Creek deposit Number 1 in Stevens County (fig. 216), and in the profile in the Loon Lake deposit (fig. 224) in the same county. Similar but less pronounced differences also occur in other deposits. To what extent this may be due to the influence of wind and to what extent it may be due to inwash has not been determined.

Efforts have been made to determine the sources from which the pumicite came and the approximate dates at which it was ejected from these sources. The principal sources in Washington are Glacier Peak and Mount St. Helens. Possibly some may have come from sources in Oregon. Hansen (1947) suggests that the volcanic ash in some Washington peat deposits came from an eruption of Glacier Peak which occurred possibly about 6,000 years ago. Carithers (1946) has mapped the distribution of pumice to the east of Glacier Peak, and he has shown the distribution of pumice to the north and east of Mount St. Helens from two eruptions which occurred during postglacial time. The two eruptions were separated by a long interval of time, the latest being possibly as recent as 1802 or 1803 (Carithers, 1946, p. 16-17). Glacier Peak and Mount St. Helens, however, probably do not account for all of the pumicite found in Washington peat deposits, and other undetermined sources, either local or more distant, seem likely.

The pumice deposits of the state can be traced to their sources simply by noting the distribution of the deposits with respect to the volcanic peaks and by noting the fairly uniform gradation of thick deposits of coarse pumice fragments near the source volcanoes to progressively thinner deposits of finer material farther from the source. However, the origin of the pumicite in the peat deposits can not be so easily traced. The pumice particles were large and relatively heavy, so when they were ejected from the volcano they were carried only moderate distances by winds before falling back to the earth, but the much finer pumicite particles were carried to far greater heights and may have become distributed in several or all directions for hundreds of miles from their source.

We now know (Rigg and Gould, 1957) that most of the pumicite in Washington peat bogs came from Glacier Peak and was deposited approximately 6,700 years ago.

Some pumicite in a few deposits in southwestern Washington undoubtedly came from an eruption of nearby Mount St. Helens, and some pumicite in these and other deposits may have come from other sources, but most of the pumicite in the deposits north of a line extending approximately east and west across the state and passing a few miles south of Olympia in the western part and Spokane in the eastern part came from an eruption of Glacier Peak which ejected an enormous amount of pumice and pumicite.

This pumicite is petrographically similar to the pumicite found in the peat deposits, but this does not in itself necessarily indicate that Glacier Peak was the source of the pumicite in the peat deposits, because pumicite ejected from Mount St. Helens and Mount Mazama in Recent time is also petrographically similar, and it seems likely from what is known that the pumicite ejected by Mount Rainier and Mount Baker in Recent time is also petrographically similar.

The conclusive evidence that Glacier Peak is the source of this pumicite is that there is a progressive change in certain physical properties of the pumicite with increasing distance from Glacier Peak. These physical properties are: particle size, coefficient of sorting, crystal content, and heavy mineral content. The heavier particles of course fell from the air sooner than the lighter ones. As the pumicite was carried in all directions (but mainly eastward and northeastward) by winds and various air currents, the heavier particles were deposited near Glacier Peak and lighter particles were carried greater distances. All of the properties mentioned above decrease in numerical value with increasing distance from Glacier Peak. The numerical values showing these decreases were determined in samples taken along four lines radiating from Glacier Peak. One line extends southwestward 125 miles to the Belmore deposit near Olympia; the second line extends 120 miles westward to the Chimacum deposit west of Puget Sound; the third line extends approximately 100 miles northwestward to the Pangborn Lake deposit near the Canadian border; and the fourth line extends 450 miles eastward to the Bailey Lake deposit in the vicinity of Spokane.

The date of the Glacier Peak eruption which ejected this pumicite was determined by radiocarbon dating of samples of peat taken just under the layer of pumicite. Samples were taken from two deposits—Moss Lake and Covington, both in King County. The determinations were made at Palisades Geological Observatory by Dr. J. L. Culp of Columbia University.

CHAPTER III

ORIGIN AND DEVELOPMENT OF PEAT DEPOSITS

Peat deposits originate in depressions and on undrained or poorly drained flats. Communities of plants grow in these places, and the course of development of the deposit is indicated by the layers of peat formed by their remains and also to a certain extent by the plants now growing on the surface. The general course of development is conveniently traced by considering the origin of the depression first and following this with a discussion of the plant communities which have formed the peat.

DEPRESSIONS

The depressions in which peat deposits in Washington have been laid down owe their origin to geologic, physiographic, and other phenomena, some of which occurred long ago and some of which are still going on. The following list of agents which have operated in forming these depressions and the ways in which they have operated, along with a few examples of peat deposits which have originated in each of these ways, will furnish a basis for discussion.

I. Water
  - A. Irregular surfaces on glaciofluvial material
    Examples.—Belmore and Lake Susan deposits, Thurston County; Spanaway Lake Number 1 and Number 2 and Parkland deposits, Pierce County; and Pangborn Lake deposit, Whatcom County
  - B. Irregular surfaces on piedmont fluvial deposits
    Example.—Deposits in the swamp forest in the Quinault Indian Reservation, Grays Harbor County
  - C. Valleys or stream channels dammed by glacial drift
    Examples.—Chimacum deposits, Jefferson County; and Happy Valley-Evans Creek deposit, King County
  - D. Valleys of tributaries dammed by aggrading of main stream
    Examples.—Saltese Marsh deposit, Newman Lake deposits Numbers 1, 2, and 3, and Liberty Lake deposit, Spokane County; and Milton deposit Number 1, Pierce County
  - E. Valleys dammed by alluvial fans from tributary streams
    Examples.—Deep Creek deposits Numbers 1, 2, and 3, Stevens County
  - F. Locally overdeepened, now abandoned stream channels
    Examples.—Crab Lake deposit, Grant County; and Creston Marsh deposit, Lincoln County
  - G. Depressions in flood plains
    Examples.—Orchards deposit, Clark County; Portage Creek deposit, Snohomish County; Stuck River deposits Numbers 1 and 2, Pierce County; and Aries Farm deposit, King County
  - H. Isolated lagoons or dammed mouths of valleys resulting from deposition of sediments by sea waves and currents
    Examples.—Ocean Dune deposit, Grays Harbor County; and Crockett Lake, Hancock Lake, and Swantown deposits, Island County

II. Ice
  - A. Irregular morainic surfaces on glacial till
    Examples.—Eloika Lake deposit, Spokane County; Mountain View deposit, Whatcom County; Fircrest deposit, Pierce County; Panther Lake deposit, King County; and Cranberry Lake deposit, Snohomish County

III. Wind
  - A. Depressions or undrained flats between adjacent dunes or in places where drainage is obstructed by dunes
    Examples.—North Bay areas, Grays Harbor County; Peninsula deposits, Pacific County; and Grayland deposits, Grays Harbor and Pacific Counties

IV. Earth movements
  A. Landslide depressions
    Example.—Beehive Mountain deposit, Chelan County; and Cayuse Meadow deposit, Skamania County
  B. Craters
    Example.—Carp Lake, Klickitat County (The peat in this lake has not been investigated.)

V. Animals (secondary agents)
  A. Drainage from depressions due to other agents further obstructed by beaver dams
    Examples.—Beaverton Valley and Spencer deposits, San Juan County; and Haviland Meadows deposit, Stevens County

VI. Plants (secondary agents)
  A. Drainage from flats or saucer-shaped depressions further obstructed by living plants or their remains
    Examples.—Lost Creek deposit, Pend Oreille County; and Northwood and Custer deposits, Whatcom County

The examples given above are clear as to the agent involved and the way in which it has operated. There are many other examples in which the evidence is sufficient to indicate strong probability but not for positive conclusions, and there are some in which it is sufficient only for a guess. For some deposits the knowledge of the geologic and physiographic phenomena is incomplete, for others the investigation of the present conditions is insufficient, and for a few the knowledge along both lines is very incomplete. It seems probable that future investigations will confirm a good many of the tentative conclusions which have been reached, but will lead to different conclusions in regard to some deposits. These limitations should be kept in mind in reading the following discussion and also in reading the descriptions of individual deposits in chapter IV.

It is evident that the outline given above oversimplifies the operation of some agents, because some depressions probably originated through a combination of agencies. The list does not give sufficient emphasis to glaciation as a factor in the formation of depressions. Glaciation and the attendant and subsequent phenomena have probably been responsible for the formation of more than 85 percent of the peat-containing depressions in the state.

Some explanations of individual categories should be made. Depressions in piedmont fluvial materials occur in Grays Harbor County. The ones observed there are in the extensive swamp forest covering several sections in the Quinault Indian Reservation. Depressions are probably numerous in this swampy region. It seems quite probable that the Carlisle Lakes peat deposit lies in such a depression, and Carlisle Prairie may have a similar origin. The depressions in fluvial material in this region are comparatively shallow.

Depressions in valleys or stream channels dammed by glacial drift occur in both eastern and western Washington. The Lakeside deposit and the Meadow Lake deposit, both in Spokane County, lie in scabland channels, and it is probable that local overdeepening of these scabland channels was the main factor in forming these depressions, but the channels have been blocked in part by glacial drift. The dams behind which lie the Chimacum deposit in Jefferson County and the Happy Valley-Evans Creek deposit in King County are made up of glacial drift which came from the Vashon ice.

Depressions in flood plains of rivers have originated in two principal ways. These are (1) abandoned river channels, and (2) depressions close to higher land which lie behind natural levees formed by aggrading along the bank of the stream after the present channel was established.

Examples of peat formation in old river channels are the Portage Creek deposit (map, fig. 184) in Snohomish County and the two Rockett deposits along the Toutle River in Cowlitz County. The Rockett deposits, however, are not at the present level of the river but are on old terraces of the river above its present level. Deposits behind natural levees along rivers are easily identified. Examples are the Ebey Island deposits (map, fig. 177) in the valley of the Snohomish River in Snohomish County and the Ames Lake Creek deposit (map, fig. 38) in the valley of the Snoqualmie River in King County.

The isolation of lagoons of salt water or brackish water by the building up of ridges of sand and gravel by waves and currents is common on the coast of Washington. The configuration of the coast line and the direction of the currents are favorable to this aggradation on the west shore of Whidbey Island, and the Crockett Lake deposit (map, fig. 23) and the Hancock Lake deposit (map, fig. 25) are the results. This phenomenon is common also in the San Juan Islands. The Spencer salt marsh on Lopez Island and the Canoe Pass lagoon and salt marsh on Shaw Island are examples, but no peat of any consequence has been formed in them. The damming of valleys by bars has been less commonly observed on the Washington coast, but the Swantown deposit (map, fig. 22) on the west coast of Whidbey Island is an example of such a depression in which peat has accumulated.

PEAT ACCUMULATION

The essential facts in regard to the deposition of peat in Washington can be conveniently grouped under two headings, (1) deposition in lakes and (2) deposition in marshes and swamps. Although some peat deposits occur adjacent to creeks or rivers (e. g., the Black River deposit [map, fig. 226] in Thurston County), in most of these the streams found their present channels on the deposits after peat deposition had been extensive, and the deposits originated in either a lake or a marsh rather than in the streams. The boundary line between the lake origin and the marsh origin is not always sharp, and it is often difficult to determine whether the peat was deposited in a very shallow lake or a deep marsh. The classification is, however, a convenient one.

A peat deposit in a lake may consist of (1) only a thin ring around the margin of the lake, (2) a more extensive area with only a small lake or pond remaining in the center, (3) a deposit in which the lake has been completely filled with peat and thus obliterated, or (4) a deposit bordering only a part of the lake shore. A deposit of the first kind represents an early stage in bog development; one of the second kind, a middle stage; and of the third kind, a late stage. Naturally, all stages between these occur. A glance at the maps of a few deposits will suffice to make this clear. Examples of the first kind are the Mary Shelton Lake deposit (map, fig. 202) in Snohomish County and Panther Lake deposit (map, fig. 58) and the Bingaman Lake deposit (map, fig. 75) in King County. Examples of the second kind are the deposit west of Ames Lake (map, fig. 72) in King County, the Woods Creek deposit (map, fig. 200) in Snohomish County, and the Miller Lake deposit (map, fig. 27) in Island County. Examples of the third kind are the Crab Lake deposit (map, fig. 17) in Grant County, the Hamilton deposit (map, fig. 171) in Skagit County, and the Covington deposit (map, fig. 45) in King County. Deposits of the fourth kind may occur in an embayment of a lake (Curlew Lake deposit in Ferry County), at one end of a lake (the Fish Lake deposit [map, fig. 3] in Chelan County), or along the side of a lake (the Lake Leota deposit [map, fig. 79] in King County). They show various stages of development.

The principal ways in which peat has been deposited in lakes in Washington are (1) the growth of plants in the shallow margins, (2) the formation of mats on the surface of the water, and (3) the growth of microscopic plants in the water. Considerable quantities of leafy herbaceous plants grow on the bottoms of lakes, and in some deposits they form appreciable amounts of peat. The same is true of unattached plants which float on the surface of the water.

Dense growths of sedges, cattails, tules, bulrushes, pondweeds, scouring rushes, marestail, *Dulichium*, water lilies, water shields, buckbean, and other plants occur in the shallow margins of lakes, and their remains often form peat. If disintegration and decay are extensive and mineral matter is washed in, they may form muck.

Extensive mats of vegetation, usually beginning at the shore, spread over the surface of lakes. Many of them begin in the mass of vegetation growing in the shallow lake margin, and some of these plants survive in or on the mats. Sedges commonly take an important part in the formation of these mats, and the term sedge mats is commonly used to designate them. In some mats *Sphagnum* has taken such an important part that they are known as sphagnum mats. Naturally, some gradations between these two occur, and mats so formed are called sedge-sphagnum mats.

Mats enlarge by the activities of several species which grow forward into the water at the margin of the mat and are followed by others. This process may continue until the entire surface of the lake is covered by the mat and the lake is thus obliterated. At its margin the mat is usually so thin that it sinks under the weight of a man, but the older parts are thicker and furnish firmer footing. Some very old mats are so firm that they are used for pasturage or hayfields or even truck farms.

The advance of a mat on open water is usually accomplished by herbaceous species whose rhizomes grow in water, but in some places the stems of small shrubs are the pioneers in the advance. Sedges and buckbean are examples of the first, and Labrador tea and bog laurel, of the second. The herbaceous rhizomes produce stems which grow upward into the air, and the tips of the woody stems of the shrubs also curve upward into the air. In both methods of advance the pioneers are followed by other species which thicken and strengthen the mat. Many species function in various ways as pioneers in the advancement of mats, but details are not necessary for a general understanding of the advance of mats of vegetation on open water. Some species which normally grow in the lake margin survive in mats. Water lilies are common in the newer parts of mats and some persist even in rather mature mats. Their rhizomes and roots are in the mud at the bottom of the lake, and their leaves and flowers project above the mat. Mosses and other plants grow close around the leaves and flower stalks and eventually choke them out.

As a mat becomes older, various herbaceous species gain a foothold on it and their roots and rhizomes help to strengthen it. At a later stage shrubs grow on it and their roots contribute to its further strengthening. At a still later stage trees may grow on it and their roots, crossing and recrossing and often forming grafts at points of contact, form a firm mat. Of course any one of these three may be the mature stage, and herbaceous mats, shrub mats, and forest mats are common.

At any of these stages the mat may become so heavy that it sinks, but there is less evidence of the sinking of forest mats than of the other two kinds. It seems probable that much fibrous peat is formed by the gradual thickening and sinking of mats, but it is also possible that some mats may have been formed when the level of the lake was lower. Landslides or beaver dams often raise the level of lakes, and drainage may be obstructed in other ways. Peat may also be deposited by disintegration and sinking of material from the bottom of the mat, and no doubt much fibrous peat is formed in this way.

The growth of microscopic plants in the water contributes to sedimentary peat (see chapter II for description). These plants are mostly one-celled or filamentous green and blue-green algae, and diatoms. As previously mentioned, small animals grow in the water while peat is being formed. Sponges grow in the water, and their spicules are recognizable in sedimentary peat. The remains of minute aquatic animals (insects, crustaceans, water fleas, water mites, and others) are also minor contributors to the formation of sedimentary peat, and their hard parts are recognizable. Mineral materials are washed in, and they contribute to the formation of muck and lake mud. Fibers from sedges and other plants which form fibrous peat drop down from mats while the deposition of sedimentary peat is going on, and thus mixtures of sedimentary peat and fibrous peat are formed. In many deposits the line between fibrous peat and sedimentary peat is sharp, but in some deposits the transition is gradual, indicating a less abrupt change in the conditions under which peat is being formed.

Though the structure of peat deposits which have developed on marshes and swamps is relatively simple, it is often difficult to determine just how the layers of peat were deposited. The following successions of plant communities can be recognized in some deposits, however, and they furnish a convenient starting point for descriptions: (1) deposition in shallow depressions or on flats on which the vegetation is now mainly sedges and grasses, (2) deposition around the bases of dense growths of shrubs, (3) deposition in swamp forests, and (4) deposition of the remains of aquatic and semiaquatic herbaceous plants in wet places or in very shallow water where taller plants are scarce or entirely absent.

An example of the first of these conditions of deposition is seen in the marsh in the southern part of the MacAfee deposit (fig. 20) in Grays Harbor County. The deposit in Bonaparte Meadow (fig. 117) in Okanogan County is similar, but it is too deep to have a marsh origin unless the level of the marsh has been raised at least once by obstruction of drainage. Examples of the second method of deposition were seen by Rigg in 1917 near Covington in King County and near Carlisle in Grays Harbor County, but recent investigation indicates that they have been largely destroyed by man's activities. The indications are that this method of deposition has been rather common in western Washington. Examples of the third method are seen in the extensive swamp forest in the Quinault Indian Reservation in Grays Harbor County. Examples of the fourth method are seen around the margins of muddy lakes, though in many places decomposition of the plant remains and the inwash of inorganic material have converted the peat into muck. Various combinations of these four methods are seen. Rigg (1919) has recorded details of some early stages of such deposition.

The development of sphagnum bogs, as distinguished from peat deposits in which *Sphagnum* has played little or no part, merits special attention. In early stages of the development of these bogs, living *Sphagnum* forms only a thin surface layer, but in later stages it forms peat, and in very late stages where the layer of sphagnum peat is thick there may be no living *Sphagnum*. In many bogs the sphagnum peat is pure, but in some it is mixed with peat formed by *Hypnum*, pigeon wheat moss, and other mosses. Some species of *Sphagnum* are conspicuous peat formers, while others form very little peat, but this phase of peat formation has not been sufficiently studied in Washington to make any generalizations about it.

Many of the species of herbs, shrubs, and trees occurring in sphagnum bogs are different from those found in other peat deposits. Among the most characteristic herbs are sundew, cotton grass, and small white-flowered orchids. The most common shrubs are Labrador tea, bog laurel, sweet gale, and the small cranberry. The last is a small slender woody vine. The most characteristic trees are hemlock, cedar, lodgepole pine, and white pine. Spruce also occurs in some deposits.

The general course of development in many sphagnum bogs is the same as in peat deposits that do not have sphagnum. They have sedimentary peat, fibrous peat, and sometimes woody peat, but they have a layer of sphagnum peat in addition to these. In some, however, the course of development is different. *Sphagnum* often grows alone in shallow water, and other species of plants follow it in later stages of development. In many places *Sphagnum* grows forward into sedge marshes and hardhack swamps, and other plants follow it.

Many sphagnum bogs are slightly or even conspicuously higher in the center than at the margins. Bogs having this dome or ridge form are called raised bogs to distinguish them from flat bogs. Raised bogs are common in the eastern United States, but they are not characteristic in Washington. A few sphagnum bogs in western Washington are, however, sufficiently raised so that their convexity can be recognized by merely looking at them. Some are 5 or 6 feet higher in the center than at the margins, but the slopes are gentle. Lost Creek bog (profile, fig. 136) in Pend Oreille County is conspicuously raised but has an abrupt slope on only one side.

Most, but not all, sphagnum bogs have a natural "marginal ditch" between the margin of the sphagnum area and the bordering hard land. Shallow water commonly stands in this "ditch" at least during the rainy season, and the plants growing in it are marsh or swamp species rather than bog species. Sedges, skunk cabbage, hardhack, and crab apple are common, and cascara and alder trees frequently occur. All are rooted in shallow muck.

Three stages—the herb stage, the shrub stage, and the tree stage—are recognizable in the development of sphagnum bogs. These, of course, merge into one another, and some bogs show all three stages. The natural climax community is a forest, but comparatively few bogs in Washington have reached this stage. The Sumner peat deposit in Pierce County has actually reached the forest stage, and some others have approached it closely.

Sphagnum bogs are most numerous in the glaciated part of the Puget Sound physiographic province, but several occur in the comparatively flat margins of the Olympic Mountains province and the Willapa Hills province. *Sphagnum* has taken considerable part in the development of bogs in the sand dune regions of Grays Harbor and Pacific Counties. A few sphagnum bogs occur in the Cascade Mountains province, and several are in Pend Oreille County in the extreme eastern part of the Okanogan Highlands province. None have been found in the Columbia Lava Plateau province.

In Washington a layer of pumicite (see chap. II for description) is a good indicator of some phases of the development of peat deposits. Interest centers around (1) its presence or absence, (2) its situation with reference to layers of peat or other materials in the same deposit, and (3) its relative situation in different deposits in the same region.

The pumicite layer is commonly present in deposits which have a lake origin and is absent in those having a marsh or swamp origin, though there are some exceptions. In deposits having a lake origin the pumicite may not be seen in the field examination, however, because it is so scattered that it does not form a definite layer. In this instance it would be found only by microscopic examination. The absence of a pumicite layer in a deposit which has a marsh or swamp origin may indicate that the peat deposit originated after the eruption which deposited pumicite elsewhere in the same region, or it may indicate that the pumicite was so scattered that it did not form a definite layer. There is considerable variation in the situation of the pumicite layer in relation to layers of peat and other materials in the same deposit. It is often present in the fibrous peat only (e. g., the Lake Goodwin deposit in Snohomish County, fig. 195), but it is sometimes present in sedimentary peat only (e. g., the Beaver Lake deposit in King County, fig. 50), and sometimes it occurs in both (e. g., the deposit south of Lake Cassidy in Snohomish County, fig. 178). It is also occasionally present in woody peat (fig. 178) and just under a layer of diatomite (fig. 178). It thus provides an easy means of determining the relative amounts of the various kinds of peat and other materials that were deposited before and after the time of the eruption and gives information in regard to the course of development of the deposit.

Where the evidence indicates that the pumicite in a group of deposits came from the same eruption, its situation furnishes a basis for comparing the stage of development of the various deposits at the time of the eruption. A striking example of this is seen in the two Manor deposits (fig. 15) in Clark County, which are only a few hundred feet apart. At the time of the eruption deposit No. 1 consisted of 1½ feet of sedimentary peat, and afterward 11½ feet of peat was formed; whereas in deposit No. 2, 9 feet of peat was formed before the eruption and nothing but diatomite was deposited afterward. Interesting information may also be obtained by comparing the profile of the Aries Farm deposit (fig. 48) with the Ames Lake Creek deposit (fig. 38), both in King County. Probably any deposit in King or Snohomish County may be compared with any other deposit in either of these counties, as the pumicite in all of them apparently came from the same eruption.

CHAPTER IV

THE PEAT DEPOSITS

GENERAL STATEMENT

The total area of the peat deposits which have been investigated in the state is slightly more than 50,000 acres. Nearly all the deposits included in the total are at least 3 feet or more in thickness, and some are more than 50 feet. A few whose thickness, so far as known, is only 2 feet are included. In a few parts of the state (mainly Kittitas and Klickitat Counties) where there is evidently very little peat and the field work has not been sufficient to determine even approximate areas, estimates of the areas are made. Nearly all peat deposits in the state have some muck at their margins, but the total muck area thus included is small in comparison with the total peat area.

The total of 50,000 acres mentioned above does not include all the deposits known to occur in the state. In Snohomish County alone 21 larger deposits, whose estimated areas range from 10 to 500 acres and total more than 2,300 acres, as well as a number of smaller deposits which are shown on the soil map, have not been investigated. A number of known areas in other counties have not been investigated, and it is probable that some areas now unknown may be found by further search.

In several counties the total acreage of peat deposits described in this report is naturally smaller than the total area of peat soils reported and mapped in the soil surveys, because, as mentioned above, the investigation of peat deposits is not complete and also because considerable areas of peat soils (especially Rifle peat) are shallow. This difference is illustrated by a comparison of the total for peat soils with the total for peat deposits in Snohomish, King, and Kitsap Counties. The total area of peat soils reported for these three counties is 25,740 acres, while the total area of peat deposits reported in the present bulletin is only 10,287 acres.

The total acreage of peat deposits does not furnish a satisfactory basis for computation of the total volume of peat in the state, as some of the deposits are very shallow and some are more than 50 feet in depth. Any statement of total volume on the basis of the data now available would be only a guess. However, as the principal utilization of peat deposits in this state is for pasturage and the production of crops, the acreage is more significant than the volume.

The area of peat in Washington is small in comparison with areas in several other states, but it is sufficient to constitute an important resource. The acreage of peat in almost topographically flat states is naturally greater than in so mountainous a state as Washington. Minnesota, Florida, and New Jersey, for example, have large areas of peat. Alway (1920) quotes Soper's estimate for Minnesota, which places the total area originally covered with "peat deposits varying in thickness from a few inches to 50 feet or more" at about 7,000,000 acres, of which "about 5,217,000 are covered with peat at least 5 feet thick." Davis (1946) says that 16 counties in Florida have an aggregate of 3,035 square miles (1,942,000 acres) of peat deposits. Waksman and coworkers (1943) report a total of 205,831 acres of peat in New Jersey. Data for determining the exact rank of Washington among the numerous states in which peat deposits occur are not available.

DISTRIBUTION BY PHYSIOGRAPHIC PROVINCES

The topography of Washington is extremely varied, but seven natural physiographic provinces are easily recognized. Landes (1901) was probably the first to list and describe the several provinces, and in his Geographic Dictionary of Washington (1917) he discusses them more fully and shows their position on a map of the state. Since then other workers have found that these or slightly modified province designations provide a useful framework for general accounts of Washington geology and resources. The usual designations are: (1) the Olympic Mountains province, (2) the Willapa Hills province, (3) the Puget Sound province, (4) the Cascade Mountains province, (5) the Okanogan Highlands province, (6) the Columbia Lava Plateau province, and (7) the Blue Mountains province. Culver (1936, p. 15-16) says, in regard to their boundaries, "It must be borne in mind that the designations for the physiographic provinces are generalizations and subject to correction for details; that all boundaries are essentially arbitrary, these departures from strict accuracy being necessitated by a desire to acquaint the reader with the outstanding features stripped of all complicating detail."

Hansen (1947), reporting his work on fossil pollen in relation to postglacial forest succession, climate, and chronology in the Pacific Northwest, including Washington, Oregon, northern California, and northern Idaho, has described and mapped the natural areas of the region. The ones which lie wholly or partly within the state of Washington are essentially the same as the provinces described and mapped by Landes and by Culver except that Hansen treats the Coastal Strip, which embraces the margin of the Olympic Peninsula, as a separate area and does not recognize the Willapa Hills as a separate area.

The currently accepted seven physiographic provinces constitute a natural basis for the discussion of the general distribution of peat deposits in the state. The table below shows this distribution, in order of a decreasing number of peat deposits and also shows the total acreage in each province.

Distribution of peat deposits in the physiographic provinces of Washington

Province	Deposits		Areas	
	Number	Percent of total	Acres	Percent of total
Puget Sound	235	72	32,248	64
Okanogan Highlands	44	14	7,656	15
Cascade Mountains	21	6	1,535	3
Olympic Mountains	17	5	2,514	5
Columbia Lava Plateau	6	2	1,533	3
Willapa Hills	4	1	5,073	10
Blue Mountains	0	0	0	0
TOTAL	327	100	50,559	100

In this tabulation all salt marshes except three on the west coast of Whidbey Island are omitted. The reason for this is that the three included are the only ones that contain significant amounts of peat. Depressed prairies which contain only muck are also omitted, though they are discussed in the text. Some shallow deposits which contain only insignificant amounts of peat and consist almost entirely of muck or muck and pumice have also been omitted. In determining the number of deposits in each province it has been necessary to assume definite boundaries where deposits occur near the margins of provinces. In these places the boundaries have been determined on the basis of local topography and glacial history, and they are discussed under the provinces involved. The provinces are discussed in the order in which they appear in the table.

The Puget Sound Province

The Puget Sound province extends from the Canadian boundary on the north to the Columbia River on the south. In the northern part it includes two counties (San Juan and Island) which are composed entirely of islands.

The Puget Sound province is bordered on the west by the Olympic Mountain province and the Willapa Hills province. Its westerly boundary is marked by various straits and inlets to the shore of the Strait of Juan de Fuca just east of Dungeness. It continues southward west of Hood Canal along an indefinite line marking the change from lower hills to mountainous topography. South of the town of Little Rock in Thurston County no peat deposits have been found near the boundary, so its exact location for the purposes of this report is not critical. Most of the deposits thus included in the western part of the Puget Sound province lie in areas drained into either Hood Canal or the various arms of Puget Sound. The eastern boundary is the Cascade Mountains, and it is not necessary to assume a definite boundary, as no peat deposit has been found whose location with reference to the boundary is doubtful.

From its northern border to an irregular line a short distance south of Olympia this province was covered by ice during the Vashon glaciation some 10,000 years ago. Long before that, most, if not all, of it was covered by ice during the Admiralty glaciation, which may have been slightly less extensive than the Vashon, though its exact limits have not been fully determined. Between these two glaciations was the long Puyallup interglacial period.

From the southern limit of the Vashon glaciation to within a few miles of the Columbia River the surface consists largely of sedimentary and volcanic rocks of early to late Tertiary age, although in the northern part the bedrock is covered by considerable quantities of sand, gravel, and fine sediments which were washed out from the Vashon ice. Valley glaciers also contributed some material to the eastern part. For a few miles north of the Columbia River the surface material was extensively worked over by water while the river was finding its present channel.

Peat deposits are numerous in this province. Many of them are deep (as much as 50 feet or more), and several of them are extensive (as much as 2,450 acres). The 235 deposits examined in this province comprise 72 percent of the total number examined in the state, and the 32,248 acres of peat area constitute 64 percent of the total peat area in the state. Nine of the 14 deposits in the state whose area is 600 acres or more and 19 of the 21 deposits in the state whose maximum depth is 40 feet or more are in this province. As most of the peat in this province is north of the southern terminus of the Vashon glacier, it is evident that the glaciated northern part of the Puget Sound province is the principal peat region of the state. The deposits are described under the headings of the various counties in which they occur. Most of them are in Whatcom, Skagit, Snohomish, King, Pierce, Thurston, Kitsap, Mason, Jefferson, Clallam, San Juan, and Island Counties. Scattered deposits occur farther south in Lewis, Cowlitz, and Clark Counties.

In addition to these post-Vashon deposits, which are at the surface, pre-Vashon deposits of peat are fairly common, and some of these are rather extensive. Probably they are mostly interglacial. They are all covered by

Vashon drift and are chiefly exposed in sea cliffs and in the banks of ravines. Some have been found in regrades (especially in Seattle) and in excavations. Some of them contain wood and show stages in the formation of lignite coal.

Hansen (1938) has described a pre-Vashon peat deposit which is exposed in Hammer Bluff on the north side of the valley of the Green River about 10 miles east of Auburn in King County. The peat is lignified, due to the long continued pressure of the 200 feet of till which overlies it. The lignite is 18 inches thick, and it lies on an 8-inch layer of blue clay or lake mud, under which are sand and coarse gravel.

Hansen and Mackin (1940) have described a deposit which occurs in Beacon Hill in Seattle. Several lenses of peat are exposed in a landslide scarp near the Twelfth Avenue South viaduct and the Marine Hospital. "The lowest and thickest lens is about three feet thick; the lower half consisting of gray, silty, limnic peat which contains fragments of reed and sedge. This is followed upward by a series of thinner lenses of limnic peat, which contain some silt and are interbedded by layers of silt and sand." A till sheet underlies the peat, and under this is varved clay. Hansen and Mackin (1949) report two other deposits. In the sea cliff at Possession Point at the south end of Whidbey Island in Island County they found one layer 5 feet thick and four others 3 to 4 inches thick. The depth of these below the lower limit of the Vashon till ranges from 160 to 240 feet. They also found layers of pre-Vashon peat in the sides of an essentially vertical-walled ravine 1,000 feet long and about 125 feet deep in the SW¼ sec. 30, T. 29, N., R. 5 E., within the city limits of Everett. Here they found four layers 3 or 4 inches thick at depths ranging from 130 to 190 feet below the lower limit of the Vashon till. Hansen has discussed the general character and distribution of interglacial peat in the Puget Sound region and has determined the kinds of fossil pollen in the four deposits described above.

The lignitic peatlike material exposed in an excavation in the Ocean City peat deposit in Grays Harbor has not been sufficiently investigated to determine either the specific character of the material or its relation to the clay which lies above and below it and the peat which lies at the surface.

The Okanogan Highlands Province

The Okanogan Highlands province comprises the northeastern part of the state. It extends eastward from the Cascade Mountains to the Idaho border and southward from the Canadian border to the south side of the valleys of the Columbia and Spokane Rivers. In considering the distribution of peat deposits it is not important to establish its western boundary exactly because no deposits occur near it. Culver (1936, p. 18) says, "Topographically, the region is varied, having relief of well over 7,000 feet but showing little of the ruggedness that might be expected. Smooth gentle slopes are dominant, so that much of the area carries a thick soil cover." Campbell (1953, p. 137) says, "The province was almost entirely buried under ice from Canada more than once during the Pleistocene, but, from Moses Mountain east, the highest peaks and ridges projected and show that the ice was about a mile thick in the valleys." (For a discussion of the geology of this province and the origin of the depressions in relation to peat deposits, see Stevens, Pend Oreille, Spokane, Okanogan, and Ferry Counties following in this chapter.)

Of the 44 peat deposits in this province, 3 are in Okanogan County, 3 in Ferry County, 15 in Stevens County, 14 in Pend Oreille County, and 9 in the northeastern part of Spokane County. These deposits are described under the heading of the counties.

The 44 deposits in this province constitute 14 percent of the deposits in the state, and the 7,656 acres of area constitute 15 percent of the total peat area in the state (table on p. 20). Two of the 15 deposits in the state having an area of 600 acres or more and one of the 21 deposits in the state having a depth of 40 feet or more are in this province (tables on page 37). The Okanogan Highlands province ranks second in the state in the importance of its peat.

The Cascade Mountains Province

The Cascade Mountains province extends from the Canadian border on the north to the Columbia River on the south, and lies between the Puget Sound province on the west and the Okanogan Highlands province and Columbia Lava Plateau province on the east. It is a rugged region which includes five extinct volcanoes (Mount Rainier, 14,408 feet; Mount Adams, 12,307 feet; Mount Baker, 10,750 feet; Glacier Peak, 10,436 feet; and Mount St. Helens, 9,671 feet).

Twenty-one peat deposits have been reported in this province. Four of them are in Chelan County, six in Snohomish County, three each in Skagit and Lewis Counties, two in Whatcom County, and one each in Kittitas, Skamania, and Klickitat Counties. They differ greatly in elevation, area, depth, and general character. Their elevations range from 4,200 feet above sea level at the Beehive Mountain deposit in Chelan County down to 500 feet at the Hamilton deposit in Skagit County. The former is near the top of a mountain, while the latter and also the Kirk Lake deposit in Snohomish County are on somewhat elevated flats in river valleys but are close to mountains. In area, the deposits of this province range from 542 acres (the Davis Lake deposit in Lewis County) down to 1 acre (the Merritt deposit in Chelan County). The deep ones are the Mosquito Lake deposit in Whatcom County, the Fish Lake deposit in Chelan County, and the Davis Lake deposit in Lewis County. Bottom was not reached at 47 feet in the first of these; the deepest boring made in the second was 38 feet, and was probably not in the deepest part of the deposit; and bottom was reached at 47 feet in the third. The shallowest deposit (4 feet) is Robe deposit No. 2 in Snohomish County. Six deposits (the Fish Lake deposit in Chelan County, the Kirk Lake deposit and the Verlot deposit in Snohomish County, the Mosquito Lake deposit in Whatcom County, the Hamilton deposit in Skagit County, and the Cayuse Meadow deposit in Skamania County) are sphagnum bogs. The search for peat deposits in places reached only by trails is incomplete, and it seems probable that there are several deposits in addition to those that have been reported. This Cascade

Mountains province ranks third in the state in the number of deposits and fifth in the total area of the deposits (table on p. 20).

The Olympic Mountains Province

The Olympic Mountains province, as defined with reference to the character of the depressions in which peat has been deposited, includes all the Olympic Peninsula except the eastern part of Clallam and Jefferson Counties and most of Mason County. Its northern boundary is the Strait of Juan de Fuca, and its western boundary is the Pacific Ocean. It extends southward to include the valley of the Chehalis River. Its eastern boundary is the western boundary of the Puget Sound province, which has already been discussed.

The mountains occupying the central part of the peninsula are extremely rugged, and valley glaciers from them have been the origin of glaciofluvial material which has been a factor in the formation of depressions in which peat has been deposited. Hilly lowlands lie between the mountains and the coast on the west and north, and it is natural that Hansen (1947) should have included them with the flat lands adjacent to the coast under his designation of the Coastal Strip. There are also hilly lowlands and extensive flats south of the mountains, and peat deposits occur there. For discussion of the geology of the province with reference to the distribution of peat deposits see Clallam, Jefferson, Grays Harbor, and Mason Counties following in this chapter.

Seventeen peat deposits, constituting 5 percent of the total number examined in the state, occur in this province (table on p. 20). Nine are in Clallam County, two in Jefferson County, and six in Grays Harbor County. Fifteen of them are in the lowland coastal strip, and two of these are in dune depressions along the coast.

No peat deposits of any consequence have been reported in the rugged part of the Olympic Mountains. Muck ranging in depth from a few inches to 1 foot or more is common in sedge meadows even at comparatively high elevations, and a small amount of fibrous material is mixed with it in some places. Living *Sphagnum* has been found in only one. The *Sphagnum* occurs at Kurtz Lake (3,800 feet above sea level in secs. 33 and 34, T. 25 N., R. 8 W., in Jefferson County. A narrow ring of muck with some fibrous material in it surrounds the lake, and *Sphagnum* grows on the muck and in the margin of the lake. Some drainage from the lake eventually reaches the Quinault River. This lake was inspected by Rigg in 1919, and no information since that date is available in regard to the muck and *Sphagnum* occurring there. The Olympic Mountains province ranks fourth in the state in both the number of deposits and the total area of deposits (table on p. 20).

The Columbia Lava Plateau Province

The Columbia Lava Plateau province is bordered on the north by the Okanogan Highlands province, and on the west it merges into the Cascade Mountains province. It includes all of southeastern Washington except the southeastern corner, which is the small Blue Mountain province. Its topography is less varied than that of the other provinces. The principal rock is the Columbia River basalt, consisting of many overlapping flows. There are extensive areas of channeled scablands. The loessal Palouse Hills form the surface of the eastern part. The drainage goes to the Columbia and Snake Rivers by small streams, some of which are intermittent.

Only six peat deposits are known in this province—three in Spokane County, two in Grant County, and one in Lincoln County. All of them are in scabland channels in depressions due to local overdeepening or to local deposition of glaciofluvial material. In some deposits both may have been factors.

The only large deposit (1,415 acres) in this province is the Crab Lake deposit in Grant County. The deepest (38 feet) is the Fish Lake deposit in Spokane County. The Columbia Lava Plateau province ranks fifth in the state in the number of deposits and sixth in the total area of deposits (table on p. 20).

The Willapa Hills Province

The Willapa Hills province is bounded on the west by the Pacific Ocean, on the north by Grays Harbor and the Chehalis River Valley, on the east by the somewhat indefinite border of the Puget Sound province, and on the south by the Columbia River. It comprises Pacific and Wahkiakum Counties, the southern part of Grays Harbor County, and the western part of Lewis and Cowlitz Counties. It is hilly, but most of it is less than 2,000 feet above sea level. Sand dunes are extensive along the ocean beaches in the peninsula region just north of the mouth of the Columbia River and also north of Willapa Bay.

The four peat deposits in this province are in the dune areas. They constitute only 1 percent of the total number of deposits in the state, but two of them—the peninsula deposits and the Grayland deposit—are large. The former is estimated at 3,000 to 4,000 acres, and the latter is almost 2,000 acres. The maximum depth of peat in this province is 11 feet. In considering the distribution of peat deposits in this province it is convenient to think in terms of Hansen's separation of the Coastal Strip as a natural physiographic area.

The Blue Mountains Province

The Blue Mountains province occupies the southeastern part of the state south of the Snake River, mainly in Asotin, Garfield, and Columbia Counties. The predominant rock is the Columbia River basalt, but this has been elevated and rivers have cut into it, exposing older rocks in a few places and depositing sands and gravels along their channels. Only a small part of the Blue Mountains range is in Washington, the main part being farther south in Oregon.

No peat deposits have been reported in the Blue Mountains province in Washington, but Hansen (1943a) bored sediments 4 meters (13 feet 1 inch) thick at an elevation of 7,000 feet in Oregon in the main part of the range, perhaps 65 or 70 miles south of the Washington border. It is possible that peat deposits may occur in this province in Washington, but the topography does not favor the development of any large ones.

PHYSIOGRAPHY OF COUNTIES

By Marshall T. Huntting

Chelan County

Chelan County is just north of the center of the state and has an area of 2,900 square miles, making it the state's third largest county. It is largely a rough and mountainous region lying on the eastern slope of the Cascade Mountains, but there are several broad valleys bordered by prominent alluvial terraces. These are the valleys of the Columbia River and its tributaries. The topography is that of a maturely dissected region of high relief and is dominated by prominent parallel divides which lead from the Columbia River at the eastern border of the county northward to merge with the main crest of the Cascades at the western edge of the county. From northeast to southwest these divides and the intervening valleys are: Sawtooth Ridge, Stehekin-Chelan Valley (occupied by Stehekin River and 1-mile-wide, 50-mile-long Lake Chelan), Chelan Ridge, Entiat Valley, Entiat Mountains, Wenatchee Valley, and Wenatchee Mountains. The mountains rise thousands of feet above the adjacent valleys; Mount Stuart, the highest point in the county, reaching 9,470 feet, with Icicle Creek, at 1,800 feet, only 4 miles away.

Argillites, quartzites, and schists occur in the western part, but of equal extent in that region and predominating in the northern part of the county are gneiss and granitic rocks. In the south a wide belt on both sides of the Wenatchee Valley is covered by the Swauk formation, composed of shale, sandstone, and conglomerate. The benches and terraces bordering the Columbia and tributary streams are made up of gravel, sand, and silt.

The mountains were vigorously eroded by glaciers in Pleistocene time, but ice-deposited till is not abundant. However, several stream courses were obstructed by ice or till, producing a number of lakes and poorly drained valleys, in some of which peat has accumulated.

Clallam County

Clallam County occupies practically the whole northern end of the Olympic Peninsula. It is bounded on the west by the Pacific Ocean and on the north by the Strait of Juan de Fuca. The central and southern parts of the county are mountainous, but hilly lowlands border the mountains on the west and north.

The Olympic Mountains have their center in Jefferson County but extend northward to cover more than half of Clallam County. The mountains are extremely rugged. Deep V-shaped valleys have been cut by many northward-flowing streams, most prominent of which are the Dungeness and Elwha Rivers, and by the westward-flowing Bogachiel, Calawah, and Soleduck Rivers, which combine to form the Quillayute River. These larger rivers and their tributaries and numerous smaller streams have deeply dissected the mountains, exposing steeply dipping sandstones, shales, and volcanic and metamorphic rocks in ragged ridges and peaks which reach as high as 7,015 feet. Glaciers are numerous on the highest peaks, and cirque lakes are common at slightly lower altitudes.

The hilly lowlands extend westward and northward from the mountains to the ocean and to the Strait of Juan de Fuca. In the lowlands sedimentary and volcanic rocks are covered in most places by Pleistocene continental and glacial deposits of sand, gravel, and till. Most of this area is completely dissected by small streams, but small lakes and poorly drained places are fairly common, particularly at the mouths of tributary streams. Large flat bottom lands and terraces border some of the larger streams, and these flats in many places are poorly drained, mainly as the direct result of glacial agencies. Many streams were blockaded by Pleistocene valley glaciers and by a large tongue of the Cordilleran ice sheet which occupied the Strait of Juan de Fuca. Drainage was further deranged by glacial till and outwash materials which were dumped irregularly in the valleys. Some of these materials contain kettles, and at least one kettle, at Tyee, has peat on its floor.

Clark County

Clark County comprises an area of 634 square miles bordering the Columbia River in the southern part of western Washington. The eastern half of the county lies in the foothills of the Cascades, but the western part is a flat to rolling plain.

The foothills rise to as high as 4,000 feet, but ridge tops descend westward, and, although at the south the mountains and the plain are separated along a distinct line, at the north they merge. The hills are high and steep, but slopes are not precipitous. Bedrock is predominantly basalt and allied rocks. Drainage is to the west by way of the Lewis and Washougal Rivers and their tributaries, all of which, with the exception of the main stem of the Lewis, flow in valleys that are narrow and V-shaped. The area is remarkably free of lakes or swamps.

The plain is flat to undulating. Over most of the area it ranges in altitude between 200 and 300 feet, but in a broad belt at the north it rises rapidly to merge with the foothills. It is sharply terminated at the south and west by 100- to 200-foot banks along the Columbia River. Bluffs of similar height border the flat-bottomed valleys of the Lewis River, Salmon Creek, and Burntbridge Creek where they cut across the plain. These valleys range in width from a mile to less than a quarter of a mile. Some of the tributary streams have cut short gulches, but others flow in shallow channels barely below the surface of the plain. Bedrock is covered in most places by deep soil and Pleistocene alluvial deposits of sand, gravel, and clay. Peat occurs in three places on the plain, according to the soil map of southwestern Washington. (Mangum, 1913).

Peat occupies a basin of about 450 acres at Fargher Lake in the northern part of the county in the area where the plains and foothills merge. The origin of this basin is not known; it may be a kettle or, in view of the fact that there is a small volcanic crater at Battleground Lake only 6 miles south, this may also be a crater. A second body of peat has an average width of ¼ mile and extends for 3 miles along a channel in the center of the plain. This channel apparently was cut by a Pleistocene stream.

At present, Mill Creek flows from the south end of the channel to the East Fork Lewis River, but the peat-covered central part is low and poorly drained. The third peat occurrence is in a small semicircular area on the flood plain of the East Fork Lewis River adjacent to the valley wall 1½ miles southeast of La Center. This is in an area of poor drainage near the mouth of the river typical of flood-plain conditions elsewhere.

Cowlitz County

Cowlitz County borders the Columbia River in the southwestern part of the state. Most of its area of 1,153 square miles is rough to mountainous, but broad low flats border the Columbia, and flood plains and large flat to rolling terraces border several other rivers.

The Cascade Mountains and their foothills occupy more than half of the County, covering all the eastern part and extending westward to the Columbia River, and descending from more than 5,000 feet to less than 50 feet at the river. The western part of the county is also hilly to mountainous, having peaks that reach to more than 2,500 feet. At the west the hills are rounded and irregularly shaped, but at the east they take the form of long sharp ridges separating narrow valleys. The Cascades are drained westward by the Toutle, Coweman, Kalama, and Lewis Rivers. The latter two rivers empty directly into the Columbia, but the others are tributaries to the Cowlitz River, which flows southward through the west center of the county to enter the Columbia near Kelso. Eocene basalt forms a considerable portion of the bedrock, but other younger lavas and sedimentary rocks occur also.

The alluvial flood plain of the Columbia River in places is more than 3 miles wide. Narrower flats are common along the Cowlitz River and occur in places along some of the rivers. The valley floors are only a few feet above normal water level, and they have numerous sloughs, swamps, and flood-plain lakes. Terraces with flat, sloping, and irregular surfaces rise in steps away from the rivers, being especially well developed along the Cowlitz and Toutle Rivers. These surfaces, rising to more than 500 feet in altitude, probably are both depositional and erosional in origin, and the underlying materials include silt, sand, gravel, and indurated mixtures of these. Several large bodies of peat and muck occur in such materials around the borders of Silver Lake near the Toutle River, and two small peat bodies are on successive Toutle River terraces just above and just below the 300-foot contour. The lower terrace is more than 50 feet above the river level.

Ferry County

Ferry County includes 2,220 square miles in the central part of the Okanogan Highlands in northeastern Washington. It is bounded on the north by Canada, on the east by the Kettle and Columbia Rivers, and on the south also by the Columbia. Major physiographic features are aligned north-south, these being the valleys of the Columbia and Kettle Rivers, west of which is the Kettle Range, then the valley of the southward-flowing Sanpoil River and the northern extension of the same valley, in which Curlew Creek flows northward, and finally on the western side of the county more mountains of the Okanogan Highlands. The floors of the major valleys range in altitude from 1,289 to about 2,400 feet, and much of the surrounding highland is more than 4,000 feet above sea level, a few mountain tops reaching above 7,000 feet. However, moderate slopes and broad rounded summits are the rule, so that although the highlands are maturely dissected they are not rugged. Rocks of many types and various ages occur in the region, including Tertiary volcanics, older granites and related intrusive igneous rocks, and still older metamorphosed sedimentary and igneous rocks—chiefly argillite, quartzite, marble, greenstone, and serpentine. Locally the rocks are masked by deposits of Pleistocene glacial drift. The drift surface is characteristically irregular, but typical moraines are not common. Prominent gravel flats and terraces of silt are distributed in the highlands as well as along the major valleys. Most of the lake basins and areas of poor drainage, a few of which contain deposits of peat, muck, or marl, are underlain by glacial deposits and originated through glacial or glaciofluvial agencies.

Grant County

Grant County, with an area of 2,720 square miles, is a semiarid region of plains and rolling hills within the Big Bend of the Columbia River in the central part of the state. The entire county is underlain by Miocene basalt, which is well exposed in many coulees and scabland areas, but in many places is covered by a variable mantle of silty eolian material and elsewhere by considerable thicknesses of fluvial and lacustrine sediments that range in age from late Miocene to Recent.

The land surface varies in altitude from more than 2,700 to less than 370 feet along the Columbia River at the south. Although the land slopes and the consequent streams flow generally southwestward, some of the highest land is in the southern end of the county along the smooth crest of the prominent Saddle Mountain ridge, which crosses the county from west to east. Lower Crab Creek flows westward along the foot of the steep north slope of this anticlinal ridge and separates it from the parallel but lower Frenchman Hills ridge. North of the Frenchman Hills is the flat to gently rolling plain of the Quincy basin. East and north of the basin are the channeled scablands,[1] an area where a mantle of loess with a mature topography of low relief was vigorously eroded by glacial melt water. This water swept away much of the mantle and isolated many groups of maturely eroded loessal hills to produce an anastomosing pattern of scablands which were further eroded to make shallow channels and deeper coulees in the basalt. The channel and coulee floors bear numerous rock basins, potholes, swampy meadows, and lakes. In a few of these low places where conditions were most favorable, peat and muck has accumulated.

[1] This term was proposed by Bretz, J H., in The channeled scablands of the Columbia Plateau: Jour. Geology, v. 31, p. 617-649, 1923.

Grays Harbor County

The western edge of Grays Harbor County forms the central portion of the Pacific Coast of Washington. Rising from narrow to one-mile-wide, sandy ocean beaches are low cliffs cut in rock and slightly consolidated sand and gravel. Stretching inland from the cliffs a maximum distance of 15 miles is a slightly uplifted coastal plain, on which are low rounded hills separated by shallow depressions and flat areas locally called "prairies." This lowland, lying west and north of the Humptulips River, is one of the three major physiographic units within the county—the other units being the Willapa Hills and the foothills of the Olympic Mountains. The Chehalis River Valley separates the Willapa Hills on the south from the uplands which rise northward to the Olympic Mountains. The Chehalis River flows on a 1½- to 2-mile-wide, nearly flat valley floor which trends northward and westward from the southeastern corner of the county to the head of Grays Harbor at Aberdeen and Hoquiam. The Willapa Hills center in Pacific County but extend northward to occupy the southern one-fourth of Grays Harbor County. These rounded hills, rising to a maximum altitude of a little more than 800 feet, are dissected by the westward-flowing North River and its tributaries. The uplands which make up the foothills of the Olympic Mountains rise gradually northward from the Chehalis River to an altitude of about 5,000 feet in the northeastern corner of the county. They comprise rounded, irregular hills and ridges having fairly steep slopes cut by numerous streams tributary to the southward-flowing Satsop, Wynoochee, Wishkah, and Hoquiam Rivers. In their lower courses these rivers meander across nearly flat valley floors averaging half a mile in width. Other streams which head in the Olympic Mountains but flow southwestward or westward across the lowlands in shallow but sharply incised, youthful valleys are the Humptulips, Copalis, Moclips, Quinault, and Raft Rivers.

Extensive mud flats surround Grays Harbor, and sand dunes extend for several miles along the beaches both north and south from the entrance to the harbor. The Chehalis River Valley is floored by glacial outwash and alluvium composed of unconsolidated sand, gravel, and silt. The Willapa Hills are made up largely of sandstone, shale, and volcanic rocks of Tertiary age. In the Olympic Mountains and their foothills are similar rocks and also older, metamorphosed sedimentary and volcanic rocks. Pleistocene sand, gravel, and clay cover the lower slopes of both the Olympics and the Willapa Hills. Most of the lowland area is covered by sand, gravel, and clay, interbedded with which in many places are thin beds of very impure lignitic materials which might more properly be classed as peat (Lupton, 1914, p. 38, 43, 44, 50, 51, 53, 54). The unweathered clay is blue, and the sand and gravel in most places are reddish brown, being stained and cemented by iron oxides. There are glaciofluvial materials deposited by streams flowing from Pleistocene glaciers. The Pleistocene lignite or peat is exposed in many places along the coast and in the banks of streams. Near Copalis it is exposed in a large pit at a depth of 10 feet as a 2½-foot bed in blue clay which underlies 2 feet of peat in the Chabot bog. Beds as much as 5 feet thick are known, and in at least one place there are two beds separated by 4 feet of clay (Lupton, 1914, p. 43, 54). The Pleistocene lignite or peat is highly decomposed, and because of the high mineral content of the material and the thick overburden it probably will never have any commercial value.

The surficial peat bogs in the lowland area owe their existence in large part to Pleistocene glaciation, as do the majority of the bogs in the state. They occupy depressions in Pleistocene sediments, and the depressions probably are original depositional features. On the other hand, the bogs along the coast and adjacent to North Bay of Grays Harbor occupy depressions whose origin is independent of glaciation. These are depressions between successive sand dunes and in front of dunes which are advancing on gently sloping surfaces. Several bogs reported (Mangum, 1912) to occur in the Willapa Hills and the Olympic Mountain foothills are situated on the flood plains of the North River and tributaries to the Chehalis River.

Island County

Island County has a land area of 208 square miles, making it the second smallest county in the state. It is made up entirely of islands—Whidbey, Camano, and two tiny islands of less than 10 acres each, all of which lie at the entrance to Admiralty Inlet in Puget Sound. The two larger islands are narrow and irregularly elongated parallel to the inlet.

A mantle of glacial drift covers the islands except for a small area at Deception Pass at the extreme northern end of Whidbey, where metamorphic rocks crop out. The drift is well exposed in 100- to 400-foot cliffs which surround the islands on all sides except for short stretches of beach which slope gently up to the generally rolling land surface, mostly less than 400 feet and nowhere more than 625 feet above sea level. The rolling surfaces are developed mostly in clay-cemented gravel till, impermeable enough so that the depressions are poorly drained, allowing lakes and peat bogs to form; but several large flat prairies in the vicinity of Coupeville are underlain by outwash gravel and sand which are so permeable that rain water is carried away underground, eliminating surface water and preventing the accumulation of peat there. These prairies are at an altitude of 200 feet, but a number of other flat areas, which, however, are poorly drained and contain fair-size bodies of peat, are at or near sea level. Extending inland from shallow bays, some of the flats support tidal marshes under which is a little shallow mucky peat of no commercial value, but other such flats contain good deep peat adjacent to or surrounding small lakes. These latter peat bodies owe their existence to topographic features originating through the action of Pleistocene glacial agencies and altered by shoreline developments accompanying postglacial changes of sea level.

Jefferson County

Jefferson County embraces 1,747 square miles in the center of the Olympic Peninsula. The county is 24 miles wide and 75 miles long, extending eastward from the Pacific Ocean across the center of the Olympic Mountains to Puget Sound. The topography is dominated by the Olympic Mountains, but a broad dissected plateau extends westward from the mountains to the ocean, and a lowland covers the northeastern corner of the county.

The Olympic Mountains are extremely rugged, stream and glacial erosion having worn the steeply dipping sandstones, shales, and volcanic and metamorphic rocks into a series of rough peaks and steep-walled valleys. Peaks and ridges commonly attain altitudes of 6,000 feet, and glaciers are numerous, especially on 7,954-foot Mount Olympus, the highest peak in the range. Draining to the west are the Hoh, Queets, and Quinault Rivers, to the north the Elwha River, and to the east the Dosewallips and Duckabush Rivers.

The plateau west of the Olympics is completely dissected, giving a series of timbered valleys and hills and ridges, the tops of which decrease in altitude westward from more than 1,000 feet at the base of the mountains to 100 to 200 feet at the top of cliffs fronting the ocean. Unconsolidated Pleistocene sediments conceal bedrock in much of the area, but the surface of this material is mostly well drained, and few peat bogs have formed.

A considerable acreage of peat is known, however, in the northeastern lowland, particularly in the Chimacum Valley. This area was covered by Pleistocene continental ice, and it is blanketed with till and sand and gravel deposits from that ice and its melt waters. The land surface is rolling to hilly, but rarely exceeds 700 feet above sea level. Most of the area is drained by Chimacum Creek, the valley of which in plan view is Y-shaped. The two branches of the stream flow sluggishly northward in flat-bottomed valleys floored with peat for lengths of about 5 miles each and reaching to as much as ¾ mile in width. This peat apparently owes its existence to choking of the downstream end of the valley by debris from the retreating ice front.

King County

King County, with an area of 2,111 square miles, extends from the summit of the Cascade Mountains to Puget Sound and includes two large islands—Vashon and Maury —in the sound. The topography is varied but may be divided into two areal units, a western lowland and an eastern mountainous area.

The lowland abuts the mountains along a fairly distinct but irregular line running southeastward from the Snohomish County boundary near Sultan to North Bend, thence northwestward to Newcastle, southeastward to Taylor, and southward to the vicinity of Mud Mountain Dam on the White River. Thus the lowland is divided by a mountain outlier into a north and a south half. Both halves are similar in that they are covered by glacial drift, and in only a few places are the underlying hard rocks exposed. The lowlands are made up of a series of plateaus separated by flat-bottomed but steep-sided valleys. The plateaus in their broader aspects are flat-topped, but vary in altitude between 400 feet and 1,000 feet, the lower figures being for those closest to Puget Sound and the higher for those to the northeast, adjacent to the mountains. In detail, though, there are only a few flat plains or prairies; more commonly the surface is undulating and in places is terraced. Low ridges and rounded hills give a relief of less than 200 feet on the plateau surfaces, but these surfaces are sharply bounded by steep slopes which descend 200 to 500 feet to the adjacent valley floors and the shores of Puget Sound. The bounding edges are serrated by numerous short V-shaped gulches, but there are comparatively few longer, deep channels cut by post-Pleistocene streams. Numerous peat bogs and small lakes occupy basins and poorly drained areas on the plateau surfaces, these surfaces being little altered since the time of their origin beneath the continental ice sheet.

The valleys separating the plateaus have steep sides which, at the west, expose mostly glacial drift but also occasional patches of bedrock. Here the valley floors are deeply alluviated flood plains as much as 3 miles wide, but eastward they narrow, and the Green River Valley, in particular, narrows to a sharp gorge, in which coal-bearing Tertiary beds are only thinly covered by drift. Most of the streams in these valleys have their headwaters in the mountains, but a few originate in the lowlands. Those originating in the mountains are, from north to south, the Snoqualmie, Cedar, Green, and White Rivers, the central two of which combine to form the Duwamish River. Similar broad valleys are occupied by the Sammamish River, Evans and Patterson Creeks, and other small sluggish streams which lie wholly within the lowlands. These valleys, as well as those of the streams flowing across the lowlands from the mountains, were carved largely by actively eroding glacial or preglacial rivers, and their post-Pleistocene streams have accomplished very little erosion, but deposition on their flood plains has been considerable. Most of the valleys, particularly the broader ones, contain bodies of peat, some of them rather large. Part of the peat is covered by silt and clay, and some of it includes thin discontinuous layers of such materials. These layers represent deposition from floodwaters which have intermittently breached natural levies built up along the banks by deposition from heavily laden river water. Peat has accumulated between such levies and the sides of the valleys, and in other poorly drained areas resulting from normal lateral shifting of aggrading streams on their flood plains. Derangement of stream courses by the Cordilleran ice sheet contributed also to the development of areas favorable for the accumulation of peat in the valleys.

The mountainous portion of the county exhibits extreme relief, most of the peaks reaching 5,000 feet or more, whereas the principal valleys have been cut to less than 2,000 feet above sea level. The tributary valleys are narrow and steep-sided, and the intervening ridges are sharp and irregular. Many of the ridges and peaks carry glaciers and permanent snow fields. The principal streams draining the area are the Skykomish, Snoqualmie, Cedar, Green, and White Rivers, all of which flow westward, ultimately to Puget Sound. Their valleys are steep-sided, but for long stretches their floors are terraced in coarse- to fine-grained alluvium, lake sediments, and glacial debris. Lakes are numerous—most of them in cirque basins—but peat bogs are few, although two areas of peat have been mapped (Miller, unpublished map) 8 miles southeast of Enumclaw on alluvial terraces in the White River Valley.

Kitsap County

Kitsap County, with an area of 394 square miles, lies in the west-central part of the Puget Sound Basin. The land is almost completely surrounded by Puget Sound and Hood Canal, the shoreline being long and irregular, following inlets and deep indentions. One large island, Bainbridge, lies within the county boundaries.

Except for a small area of about 17 square miles west of Bremerton, where the Blue Hills rise to almost 1,700 feet above sea level, most of the land surface is an undulating plain lying below the 400-foot contour. Rising from narrow beaches to this plain are bluffs and steep rises in which are exposed glacial deposits which range in thickness from a very few feet to more than 1,000 feet. The plains include large flat areas, in some of which are shallow depressions, as well as undulating to gently rolling hills and ridges which have a pronounced northeast-southwest alignment. This alignment is followed also by the streams. The streams are small and only a few are perennial. They flow in narrow steep-sided valleys and ravines, and most of them have very few tributaries. Thus it is clear that the topography of most of the county is not only developed in glacial deposits but is the constructional product of continental glacial agencies and has been only slightly altered by postglacial erosion. Hence, many shallow depressions in which peat has accumulated are found in all of the county except the small Blue Hills area west of Bremerton.

The Blue Hills comprise a group of timber-covered rounded individual hills, at least 17 of which rise more than 1,000 feet above sea level. The hills are closely spaced but are separated by small streams draining radially away from the center of the group. Thick deposits of glacial materials cover the lower slopes, but in the central part there are basaltic lava flows, tuffs, and agglomerates (Weaver, 1937).

Kittitas County

Kittitas County comprises 2,315 square miles in the central part of the state. It averages 35 miles in width and extends southeastward from the crest of the Cascade Range to the Columbia River, a distance of 80 miles. Except for a narrow belt along the Columbia, the whole area is drained by the Yakima River and its tributaries. Elevations range from 475 feet at the Columbia River to 5,000 to 8,000 feet at the peaks in the Cascades. The mountains at the west and along the northern edge of the county are rugged. They are made up of many different rock types, including igneous, sedimentary, and metamorphic rocks of various ages. Prominent ridges flank the mountains and extend southeastward across the county with decreasing altitudes to merge in part with extensive areas of low-dipping and flat Columbia River basalt at the east. The Yakima River heads in the Cascades and flows southeastward through the central part of the county in a broad, flat-floored valley. Near Teanaway the valley narrows to a steep-sided canyon, through which the river flows for 6 miles. At its lower end the canyon opens out into Kittitas Valley, which is a roughly oval-shaped basin, about 25 miles long and 14 miles wide. The river flows along the southwestern side of the basin and then turns southward, cutting across the Manastash and Umtanum Ridges through a deep, tortuous canyon.

The eight areas of peat which have been mapped (Smith, Dwyer, and Schafer, 1945) are all in the upper part of the Yakima Valley. They lie on alluvium and owe their existence to topographic features developed through glaciation.

Klickitat County

Klickitat County, in south-central Washington, is 84 miles long and averages 25 miles in width. The Columbia River forms the southern border of the county. The river flows in a deeply cut valley, the "Columbia Gorge ", and even at the eastern end of the county the channel is only about 250 feet above sea level. Sand and gravel terraces border the river in places. The northern part of the county is mountainous; the rest is high and rolling and slopes gently to the south. In the western end of the county the streams flow in deeply incised valleys. To the east the land surface is rolling and the valleys are less pronounced. The two largest rivers, the White Salmon and the Klickitat, flow southward and southwestward to the Columbia in the western part of the county. To the east the streams are smaller, and they flow southwestward in pronounced parallel courses.

Basaltic lava flows underlie the surface in almost the entire county. Soil cover in most areas is relatively thin. Most of the basalt is Miocene in age and is part of the extensive plateau basalts that cover the whole of the central and southeastern part of the state. However, large areas in the northern part of Klickitat County are covered by younger basalts, which also fill part of the canyons of the White Salmon and Klickitat Rivers. The peat near Glenwood accumulated in an area in which the drainage was disrupted by these younger flows.

Lewis County

Lewis County includes 2,369 square miles in central southwestern Washington and extends about 95 miles westward from the crest of the Cascade Mountains through the southern extension of the Puget Sound Basin into the Willapa Hills. The Willapa Hills center in Pacific County, but extend eastward to cover about 400 square miles in the western end of Lewis County. These hills are steep but not precipitous, and they rise westward to a maximum of 3,111 feet at Baw Faw Peak. Tertiary sedimentary, pyroclastic, and volcanic rocks have been maturely dissected by numerous streams which join the Chehalis River and flow northeastward out of the hills and into the lowland.

The rugged Cascade Mountains and their foothills cover the entire eastern half of the county. The bedrock is predominantly Miocene lava, but there are lesser amounts of older and younger lavas and older sedimentary rocks, all exposed in sharp ridges and deep valleys cut by the Cowlitz River and its tributaries, which form the principal drainage system in the eastern end of the county.

The Cowlitz River flows westward into the lower Puget Sound Basin, then turns southward. The remainder of the basin is drained to the north by the Chehalis River and several of its tributaries. This basin area extends across the county from north to south, somewhat west of the center of the county, lying between the Willapa Hills and the Cascade Mountains. This is a region of low relief, and the highest points are mostly less than 800 feet above sea level. Broad flat- to undulating-surfaced terraces cut in Pleistocene sediments rise in steps from the flood plains of the larger rivers. Small streams in places have cut deep channels and have added considerably to the surface details, but the terraces are the basic topographic features of the whole lowland area. These terraces and the flat river-bottom lands also extend far back into the mountains both to the east and west along the ¼- to 2-mile-wide valleys of the Cowlitz and Chehalis Rivers and their tributaries. Many of the terraces appear to have had an erosional origin, but others, particularly several of those where peat has accumulated, apparently had depositional origins.

Eight or more peat areas have been mapped (Fowler and Ness, 1954) in the county. All of them are on flood plains or terraces, and most of them occupy shallow basins at the mouths of tributary streams where rapidly deposited fluvial plains were built up in the main valleys, forming low dams at the mouths of the tributaries.

Lincoln County

Lincoln County embraces 2,302 square miles in central eastern Washington and lies wholly within the Columbia Lava Plateau physiographic province. Miocene basalt underlies most of this region, and older rocks are exposed at only a few places in the east and north. Although much of the basalt is well exposed, it is mantled in many places by loess as much as 200 or more feet thick.

Along the northern boundary of the county the land rises abruptly from an altitude of 1,289 feet at the Spokane and Columbia Rivers (backwater from Grand Coulee Dam) to the edge of the lava plateau, which slopes gently southwestward and varies in altitude between approximately 2,000 and 2,500 feet. The plateau topography is characterized by the channeled scablands,[2] which produce an anastomosing pattern over nearly the whole county. Among the scabland tracts are isolated patches mantled largely by loess, which has a mature topography of gently sloping low hills. The scablands are areas where Pleistocene erosion removed the mantle, exposed the underlying basalt, and abraded in the basalt thousands of channels varying from a few feet to hundreds of feet deep. Most of the channels are dry, but a few contain small intermittent streams. The channels are interlaced, producing among them a multitude of butte-like hills, flat-topped mesas, and ridges of rock. The walls of the channels in most places are steep cliffs, and on the floors are dry falls, abandoned cascades, rockbound lakes, potholes, ponds, swampy meadows, and deserted water courses. Some of the rock basins were produced by plucking of the columnar basalt in the canyon floors where the gradient was high, and others were produced as plunge pools at the base of receding cataracts.

[2] This term was proposed by Bretz, J H., in The channeled scablands of the Columbia Plateau: Jour. Geology, v. 31, p. 617-649, 1923.

Lakes and closed basins in the county are numerous, but they are restricted to the channeled scabland tracts. Very few of them contain peat, apparently because of the combination of a semiarid climate and the unfavorable environment of the basins themselves, most of which are deep, rocky, and steep-sided.

Mason County

Mason County includes an area of 930 square miles just west of the southern end of Puget Sound in the west-central part of Washington. A long, extremely irregular coastline is afforded by the ramifying arms and inlets of Puget Sound and Hood Canal. Two large islands, Hartstine and Squaxin, lie within the county boundaries. The northwestern portion of the county reaches into the Olympic Mountains, but the rest is a region of plains and rolling hills.

The Olympic Mountains comprise an area of extreme relief. In Mason County they rise westward from sea level at Hood Canal to a maximum height of 6,434 feet at Mount Skokomish in a distance of 12 miles. In the high country, folded Tertiary and possibly older sandstones, shales, and volcanic rocks have been deeply eroded into a series of rugged peaks and steep-walled valleys by the Hamma Hamma and Skokomish Rivers and their tributaries. In the foothills the older rocks have been covered by glacial drift.

The eastern and southern portions of the county are regions of low relief, characterized by broad plains and low hills composed of till and outwash sands and gravels. North of Shelton and east of Hood Canal the topography is similar to that in the adjacent portion of Kitsap County. A series of long low rounded parallel ridges having pronounced northeast-southwest alignment contains only a few similarly aligned small streams and a few tributaries. There are, however, numerous small lakes, marshes, and peat bogs. West and southwest of Shelton, outwash gravel and sand form a number of nearly flat prairies separated by low rounded hills. Most of this area is drained to the southwest by the East Fork of Satsop River and by Cloquallum Creek, tributaries to the Chehalis River. South and east of Shelton, rounded hills of drift and drift-covered bedrock rise to as much as 1,400 feet. Mill Creek and Skookum Creek, the principal streams draining the area, flow northeast to Puget Sound.

Peat is found in all parts of the county except the high Olympics. Whenever glacial deposits are found—even including the Olympic foothills—there also are peat bogs. Most of the depressions now occupied by peat were formed in ground moraine under the ice and in irregularly deposited outwash materials from the Pleistocene continental ice sheet which occupied Puget Sound Basin. Several bogs in stream valleys owe their existence to local obstructions in the valleys, some of which are direct products of glaciation.

Okanogan County

Okanogan County, with an area of 5,221 square miles, is the largest county in Washington. It lies along the central part of the northern border of the state and reaches eastward about 90 miles from the crest of the Cascade Range to the Ferry County line, and southward an average of 65 miles from the Canadian boundary to the Columbia River. Thus, the western one-fourth of the county, west of Chewack Creek and the lower Methow River, lies in the Cascade Mountains, and the eastern three-fourths is in the Okanogan Highlands.

Two broad valleys cross the county from north to south, the Methow in the west and the Okanogan in the center, separated by the Okanogan Mountains, which rise to the north to more than 8,000 feet above sea level. These valleys and that of the Columbia River are characterized by prominent but discontinuous terraces of gravel, sand, and silt of Pleistocene age. The terraces are at various levels up to several hundred feet above the river channels.

In the western part of the county the Cascade Mountains are a series of rugged peaks and ridges of intrusive igneous and metamorphosed sedimentary rocks. Many of the summits are above 8,000 feet. To the east in the Okanogan Highlands the mountains are much less rugged, and moderate slopes and broad rounded summits are the rule. Most abundant in this region are metamorphosed Paleozoic sedimentary and igneous formations along with younger intrusive igneous rocks. However, in the south-central part of the county horizontal flows of Tertiary basalt make up a large plateau and several smaller remnants which are extensions of the Columbia Lava Plateau to the south.

The numerous small lakes and ponds scattered over the Okanogan Plateau have no surface outlets, and their waters are saline. Their basins are of glacial origin, but none of them is known to contain peat. Although all of the county except for some of the highest peaks was covered by Pleistocene ice sheets, the ice did not greatly modify the general surface features. Some rock surfaces were rounded and smoothed, and in places shallow rock basins were gouged out. Elsewhere some valleys were dammed with drift, and irregular deposits of drift on plateaus and gentle slopes left numerous undrained hollows, but in very few of these topographically favorable places did peat accumulate.

Pacific County

The southwestern section of the Pacific coast of Washington forms the western boundary of Pacific County. Most of the county is characterized by the topography of the Willapa Hills. These hills (they would be called mountains in many parts of the United States) extend from the Columbia River northward across the country to Grays Harbor and the lower Chehalis River. They front Willapa Harbor and extend eastward to the southern part of the Puget Sound Basin, beyond the eastern border of the county. The highest peak, just over 3,000 feet, is near the southeastern corner of the county, and near it are several other peaks above 2,500 feet, but the hilltops decrease in altitude gradually northward and westward. There are numerous large streams draining radially from the hills, and they have countless tributaries, making a very complex network that dissects the area into a maze of forested hills. The bedrock is a series of Tertiary sedimentary, pyroclastic, and volcanic rocks, including shale, mudstone, sandstone, tuff, agglomerate, and basalt.

The central western part of the county is indented by Willapa Bay, and all the larger streams which flow into the bay have at their mouths large level salt-water marsh areas. None of these marshes is known to contain peat, but peat is found at the landward edge of such a marsh at the mouth of the Chinook River, which flows into the Columbia near its mouth. These marshes have formed through choking of the mouths of the streams by sand and mud deposits by the rivers in the quiet protected waters of Willapa Bay, and in the case of the Chinook River, at its mouth in a protected bay at the mouth of the Columbia River. Of the streams which flow into Willapa Bay, only two have comparatively level, alluvium-covered bottom lands along their courses where they extend back into the hills. These are the Willapa River and the Naselle River. The latter has a valley floor ¾ to ¼ mile wide extending from the salt marshes to the eastern boundary of the county, a distance of about 6 miles. The Willapa River, the largest stream in the county, has a valley floor 1¼ miles wide at Raymond and narrowing to about ¼ mile about 17 miles upstream to the southeast. No peat is known in the valleys of either of these rivers.

The important peat bogs in the county are found along the coast, and with the exception of the Chinook bog, all are less than a mile from the ocean beaches. These are in a sandy strip 1 to 2 miles wide fronting the Pacific Ocean in the northwestern corner of the county and in a long narrow peninsula separating the ocean from Willapa Bay. The peninsula extends 22 miles northward from North Head at the mouth of the Columbia River to the entrance of the bay. This coastal area is floored by sand derived from the river and carried northward by ocean currents. Sand beaches several hundred feet wide, which are intermittently covered by tides, are fronted by a narrow strip of actively drifting sand dunes, back of which is a series of parallel low rounded stabilized dunes, none reaching more than 50 feet above sea level. Long narrow shallow lakes and peat bogs occupy depressions between successive stabilized dunes and between the dunes and the high land which rises eastward from the south end of the peninsula and from the sandy strip north of Willapa Bay.

Pend Oreille County

Pend Oreille County, at the northeastern corner of the state, is 66 miles long from north to south and averages 21 miles in width. The valley of the Pend Oreille (Clark Fork) River is the dominating physiographic feature of the county. The river crosses the border from Idaho at Newport, near the southeastern corner of the county, flows northward through the center, and crosses the Canadian border near the northwestern corner of the county. South of Metaline Falls the valley floor varies from less than 1 mile to more than 4 miles wide, the greatest widths being at the south, in the vicinity of Usk. In the 50 miles between Newport and Ione the river has a gradient of only 0.8 foot to the mile, but northward from Metaline Falls to the international boundary, a distance of 11 miles, the river flows in a narrow rocky gorge and has a gradient of 20 feet to the mile (Marshall, 1914). Along the broad part of the valley there are two well-defined terrace levels, one at 2,100 feet in altitude and the other between 2,500 and 2,600 feet (Park and Cannon, 1943, p. 35-36), as well as other less well-defined terrace levels. The terraces are made mainly of silt and fine sands—Pleistocene lacustrine deposits—except along tributary streams, where coarse clastic materials predominate.

To the west of the Pend Oreille Valley is the Calispell Mountain Range, the spurs of which rise from the valley floor steeply at the north in the area of metasedimentary rocks but more gently at the south in the area underlain by granitic rocks. The range is described on page 33 in the discussion of Stevens County physiography.

The Kaniksu Mountain Range rises to the east from the Pend Oreille Valley to a maximum altitude of 7,318 feet at Gypsy Peak, near the northeastern corner of the county. The crestline is 6 to 12 miles east of and parallel to the river and about 5 miles west of the Idaho border. The northern one-third of the range comprises steep, rugged peaks and ridges of ancient metasedimentary rocks; the central portion is underlain by granitic rocks, and the peaks are less rugged and lower in altitude; and the southern one-third is an area of metasedimentary rocks, in which the peaks are decreasingly lower toward the south. Numerous small streams flow from the range westward to the Pend Oreille River and eastward to the Priest River in Idaho. The valleys of most of these streams are floored with fine to coarse, unassorted glacial debris. The Cordilleran ice sheet covered all but the high peaks, leaving characteristic erosional and depositional modifications of the pre-existent topography.

An area of about 200 square miles in the south-central part of the county is a lowland covered by till and glaciofluvial sand, gravel, and silt, through which project low hills of granite and metasedimentary rocks. This area was completely covered by the continental ice sheet. The clastic materials that were laid down as the ice advanced and retreated—probably several times—are glacial lake deposits, stratified drift, and till. These deposits occur as river terraces, moraines, and boulder-strewn plains.

All the known peat bogs in the county owe their existence to the effects of glaciation. The continental ice sheet advanced southward to cover practically the whole county two and possibly more times during Pleistocene time (Park and Cannon, 1943, p. 35). As a result, numerous depressions without surface drainage were left among the widely spread deposits of glacial debris. These depressions formed where valleys were dammed by stratified drift or till, where remnant blocks of stagnant ice melted, and between successive recessional and ground moraines. Many of the depressions are now occupied by lakes or peat bogs or both.

Pierce County

Pierce County, in west-central Washington, has an area of 1,701 square miles. It extends eastward from the southeastern part of Puget Sound to the crest of the Cascade Mountains, thus including elevations ranging from sea level to 14,408 feet, at the summit of Mount Rainier. The county boundaries extend across Puget Sound to include three large islands, Fox, McNeil, and Anderson, and two peninsulas, comprising about 100 square miles, which jut southward into the sound from Kitsap County. Topographically, the county may be divided into a western lowland and an eastern mountainous area.

The lowland covers the western half of the county, ending abruptly at the base of the Cascade foothills along a line running northeastward from LaGrande to Buckley. From this line the land slopes gently westward from an altitude of about 750 feet toward Puget Sound, dropping off sharply in bluffs 100 to 300 feet high along the shores of the sound. In the whole area only glacial and glaciofluval deposits are exposed. In the central section outwash materials—mostly gravels with a surface intermixture of black silt—floor wide treeless prairies, which in places are perfectly flat, in other places have low rounded hills and ridges, and elsewhere are pitted by kettles and shallow depressions. Still other areas are terraced in benches 1 to 20 feet high. The gravels are very permeable, and most of the rain water is carried away underground. Clover Creek and Muck Creek, the small ineffectual streams which drain this rather large area of prairies, flow sluggishly in channels interrupted by many small lakes and bordered in part by peat.

The islands and peninsulas in the western part of the county are covered by till, which has an irregular surface left by the retreating Pleistocene continental ice sheet. Interspersed among rounded hills and ridges of low relief are several lakes, swamps, and peat bogs.

The eastern part of the lowlands is also covered by till and minor amounts of stratified drift. Here is a series of plateaus divided by interconnecting, flat-bottomed, alluviated valleys ¼ to 2 miles wide. These are the valleys, in order from north to south, of the White, Stuck, and Puyallup Rivers, South Prairie Creek, Carbon River, and Ohop Creek. Steep gradients along their upper courses in the mountains to the east change sharply to very low gradients in the broad lower valleys, where the overloaded streams are currently depositing part of their loads in their channels and along their banks, thus building low, natural levies. Between the levies and the valley sides are poorly drained areas, in some of which there is peat, typically interlayered with thin discontinuous bands of clay representing deposition from floodwaters which have intermittently breached the levies.

The plateaus are essentially flat-topped, though diversified by hills and trenched by shallow channels, and they are bounded by steep slopes descending 200 or 300 feet abruptly to the valley floors. Ridges which rise 25 to 100 feet above the general level trend northwestward at the north, whereas at the south their trend is northeastward. The retreating ice left depressions among the ridges, and poorly drained areas along confusedly obstructed channels. Post-Pleistocene stream erosion has done little to alter the glacial topography, hence there remain numerous basins containing lakes, swamps, and bogs.

The eastern half of the county exhibits extreme relief. The western toe of the foothills is blanketed by glacial debris, but to the east are successive belts of Tertiary volcanic rocks, sandstone and shale, and then volcanic rocks again, extending to the crest of the Cascade Mountains.

Several small areas of granitic rocks are exposed. The whole area is maturely dissected into deep valleys and canyons by the White, Carbon, Puyallup, and Mashel Rivers and their innumerable tributaries. These streams all flow in sharp V-shaped valleys, except for the White River, the valley of which is steep-sided but mostly floored with flat and terraced glacial and alluvial deposits. Between the streams the intervening sharp ridges are commonly steep-sided, high, and, where above timber line, intricately serrated. The mountains, and particularly the volcanic cone of Mount Rainer, support numerous large and small glaciers. Such a mountainous area could not be expected to include large or many peat deposits; however, the terraced floor of the White River might conceivably support peat bogs, and, in fact, several mucky peat areas have been mapped there (Anderson et al., 1955) near the mouth of the Clearwater River.

San Juan County

San Juan County, with a land area of 175 square miles, is the smallest county in the state. It is made up of a group of islands in Puget Sound between the Strait of Juan de Fuca and Georgia Strait. The islands range in size from the three largest, Orcas, San Juan, and Lopez (57, 55, and 29 square miles respectively), through progressively smaller islands down to small unnamed reefs and rocks which are exposed only at lower low tide, giving a total of 743 isolated islands and reefs (McLellan, 1927, p. 15).

The islands represent the higher points of a submerged mountain range of moderate relief, and the channels and harbors represent the valleys between the peaks. The shoreline is irregular and is indented by a succession of bays and small promontories. The land surface varies from low plains and broad valleys through rounded hills to rugged low mountains which rise precipitously from the water's edge. The highest point is 2,409-foot Mount Constitution on Orcas Island. The bedrock is made up mostly of pre-Tertiary indurated and metamorphosed sedimentary and volcanic rocks along with basic intrusive rocks. Glacial drift covers large areas on many of the islands, mostly at lower elevations but extending in places to the highest points. Even the top of Mount Constitution was overridden by the Cordilleran ice sheet, and on that mountain several depressions now containing peat bogs were carved out of solid rock by glacial erosion (McLellan, 1927, p. 29).

Small bogs occur elsewhere in the islands in glacially carved rock basins and in depressions in glacial drift.

Skagit County

Skagit County has an area of 1,774 square miles. It is the second county south of the Canadian border and has the crest of the Cascade Mountains as its eastern boundary and the shore of Puget Sound as its western boundary. Included are Fidalgo, Cypress, Guemes, and a number of smaller islands in the sound. The county is only 24 miles wide, but is nearly 100 miles long from east to west. Approximately three-fourths of the area is mountainous, the lowland area being in the southwestern and west central sectors.

The mountains extend westward from the 5,000- to 9,000-foot Cascade crest through all of the eastern and central part of the county and along the northern edge of Puget Sound. Several islands in the sound are mountain outliers, as is Devils Mountain, the isolated mass southeast of Mount Vernon. The mountains in the eastern end of the county comprise some of the most rugged and inaccessible terrane in the state. Numerous glaciers and permanent snowfields cling to many of the peaks above 5,000 feet. Many peaks exceed 8,000 feet, but the principal valleys have been cut to less than 1,500 feet above sea level. The tributary valleys are V-shaped and narrow, and the ridges are sharp and rough. Slopes are steep, and rock outcrops abundant. Rock types range through Tertiary sedimentaries, older metamorphics, volcanics, and intrusives, named in the order of their occurrence from west to east. Small areas are drained by streams flowing into the adjacent counties to the north and south; and a small area in the northwestern corner of the county is drained by the Samish River; but most of the mountainous area—and most of the county as a whole—is drained by the Skagit River and its tributaries.

The valley of the Skagit is flat-bottomed and terraced, and is covered with alluvium and glacial debris far back into the mountains. The valley floor is 2 to 3 miles wide as it passes westward through the mountains for 25 miles to Sedro Woolley. There the valley opens out onto flat plains which slope very gently to the sound across the 20-mile-wide delta of the Skagit. Maximum altitude above sea level on the delta surface is about 60 feet, but the lowlands include also several areas of terraces and low hills and ridges in which the general land surface rises to between 200 and 1,000 feet. In these areas the surface materials are glacial till and stratified drift, whereas the Skagit flats are floored by silt and clay.

Peat in the county is distributed in the lowland and in the valleys of the larger streams, in depressions most of which date back to Pleistocene glaciation. However, the large peat body west of Burlington lies in an area of poor drainage developed through irregular shifting of distributary streams across the Skagit River delta.

Skamania County

Skamania County, in the southern part of the state, is bordered on the south by the Columbia River and lies almost entirely within the Cascade Mountains. Except for some narrow terraces along the Columbia and a small area of gently rolling to hilly benches in the southwestern corner of the county, the land is rough and mountainous. The highest point is the 9,671-foot summit of Mount St. Helens, but the county border cuts across the western slope of Mount Adams at an altitude almost as great. Most of the land is above 2,000 feet, but the Columbia River is less than 50 feet above sea level, and the gorge through which the river flows has almost perpendicular walls in many places. Although rough and mountainous, the Cascades are less rugged here than in the northern part of the state. The mountains are dissected by the White Salmon, Little White Salmon, Wind, and Washougal Rivers, which flow southward directly to the Columbia, and by the westward-flowing Lewis River, and by the

Cispus River and other streams which flow northwestward to the Cowlitz River.

Basaltic and andesitic lavas cover almost the entire county, but there are relatively small areas of granitic and sedimentary rocks. A large area between and south of Mount Adams and Mount St. Helens is covered by lavas which flowed out comparatively recently, so recently, in fact, that the original lava surface remains almost unaltered by erosion. Consequently the surface in many places has only a gentle slope and an over-all smoothness but in small detail is rough. The lack of erosion here accounts for the fact that most of the lakes and swamps in the county are in this area.

Snohomish County

Snohomish County is the third county south of the Canadian border having the shore of Puget Sound as its western boundary and the crest of the Cascade Mountains as its eastern boundary. Physiographically it is similar to the other counties thus bounded. The eastern portion is mountainous, and the western portion is a lowland region of rolling low hills. Flowing westward across the entire length of the county are two major rivers, the Stillaguamish to the north and the Snohomish on the south.

The mountainous region, comprising about 65 percent of the county, exhibits bold, rugged topographical features, including, at the eastern edge of the county, the fourth-highest mountain in the state, 10,436-foot Glacier Peak. The whole area is one of extreme relief, most of the peaks reaching 5,000 or more feet, and the principal valleys have been cut to less than 1,000 feet above sea level. The tributary valleys are narrow and steep-sided, and the intervening ridges are sharp and irregular. Many of the ridges and peaks carry glaciers and small permanent snowfields. During Pleistocene time mountain glaciers were much larger and more active, their activity being marked now by numerous cirque lakes and basins and by glacial debris in the valleys. Aside from the valley floors, the region has little or no soil cover, the rocks exposed representing a great variety of sedimentary, igneous, and metamorphic types.

The lowland is an area of about 660 square miles lying between Puget Sound and the western edge of the mountains, in a belt 36 miles long and 12 miles wide at the northern edge of the county and 25 miles wide at the south. This region was wholly covered by the Puget lobe of the Cordilleran ice sheet, and the surficial clay, sand, gravel, and till, and most of the topographical features developed in these materials are directly or indirectly results of that glaciation. Gently rolling low hills and very shallow tributary stream channels give low relief to the land surface, which for the most part is 200 to 500 feet above sea level, but which breaks off sharply on the west to the shores of Puget Sound and on other sides to the flood plains of the principal rivers, generally less than 100 feet above sea level.

The North and South Forks of Stillaguamish River flow out of the mountains and into the lowlands to meet at Arlington, thence to meander westward along a 1½-mile-wide valley floor to Puget Sound at Stanwood. In the lowlands the principal tributary to the main stream is Pilchuck Creek. In the mountains the larger tributaries are Deep Creek and Canyon Creek, flowing into the North and South Forks respectively. Similarly, the Snoqualmie and Skykomish Rivers flow out of the mountains and into the lowlands to meet 3 miles southeast of Monroe. Below this junction the river is known as the Snohomish, and it meanders northwest along its 2-mile-wide valley floor to its mouth at Everett. The Pilchuck River is the largest tributary flowing across the lowlands to the Snohomish River. Woods Creek and the Sultan River flow into the Skykomish River in the lowlands, and in the mountains there are a number of important tributaries to the Skykomish. In all, there are about 100 square miles of level land (Anderson et al., 1947, p. 4) along the larger streams.

The peat is about equally distributed between the valleys of the large streams and the lowland hills. That in the valleys is concentrated in the western area where the streams cross the lowlands, but some is found also along the larger valleys in the mountains. The undrained or poorly drained areas in which peat has accumulated in the valleys are partly the result of normal lateral shifting of aggrading streams from side to side on their flood plains and partly the result of damming of streams by mountain glaciers and continental ice tongues with consequent derangement of drainage patterns during Pleistocene time. Among the rolling hills in the lowlands, peat is found in irregularities of the surface which are direct products of continental glacial erosion and deposition.

Spokane County

Spokane County is centrally located on the eastern border of the state. The Spokane River, flowing from east to west across the middle of the county, occupies a shallow trench in a 3-mile-wide alluvial valley that extends from east of the Idaho border to the city of Spokane. The valley floor is about 2,000 feet above sea level, which is about 400 feet lower than the Columbia Lava Plateau in the vicinity of Spokane. Within the city the river drops about 150 feet in a series of falls, and westward it flows in an alluvium-terraced rock gorge about 900 feet deep. The valley here marks the dividing line between the extensive Columbia Lava Plateau on the south and the southeasternmost extension of the Calispell Mountain Range on the north.

Granitic rocks underlie the above-mentioned hilly area, of about 40 square miles, and most of a more mountainous and much larger area comprising the whole northeastern quarter of the county. These mountains, the highest of which, Mount Spokane, reaching an altitude of 5,878 feet, are drained by small streams which have developed a radial pattern away from the central high point. South of the upper Spokane Valley is a smaller area of similar rocks in an only slightly less mountainous terrane, and extending beyond the southeastern corner of the county are "islands" or steptoes of granitic and metamorphic rocks which rise to about 1,400 feet above the surrounding lava plateau. Similar knobs and ridges form a broken east-west chain of lava-surrounded hills across the south-central part of the county, from Silver Hill to Medical Lake and beyond.

The Columbia Lava Plateau, which occupies thousands of square miles in southeastern Washington, covers the western half of Spokane County. As a whole, it is a vast plain of essentially flat-lying lava flows which have been only superficially eroded since the time they cooled. Successive flows of fluid lava advancing from the west in late Tertiary time flooded the area, leaving only the higher points of the pre-existent topography projecting through the "sea" of lava. Thus, the line of demarcation between the plateau and the mountains is fairly sharply defined. In the county the plateau has an altitude near 2,400 feet. It slopes very gently to the southwest, but north of Medical Lake the streams flow northward to the Spokane River in deeply cut canyons. In addition to the deeper canyons, the surface of the plateau is roughened by shallow steep-sided dry channels, rock-bound undrained lake basins, and shallow depressions—features described by Bretz[3] (1923, p. 573-608) as part of the channeled scablands, eroded by glacial melt water.

The Palouse Hills, extending north from Whitman County to cover about 500 square miles in the southeastern part of Spokane County, are part of the Columbia Lava Plateau but are topographically distinct from the channeled scablands to the west. The hills are rounded and mostly less than 200 feet high. They have been cut by normal stream erosion from a blanket of largely wind-deposited silt, from less than 50 to more than 200 feet thick, which overlies the basalt. Although the shape of the hills may have been altered somewhat by wind and other agencies, stream erosion has been active enough to prevent wind action from forming undrained basins in which peat could accumulate.

An isolated extension of the Columbia Lava Plateau occupying the northwestern part of the county, with Deer Park at its center, is here called the Spokane Plateau. It differs from the Columbia Plateau to the south in being about 200 feet lower in altitude and in having fewer undrained depressions on its surface. Most of the plateau is covered by glacial debris, the surface of which is level to gently sloping.

The depressions in which peat has accumulated in the county are unusual in that they include not only those formed in unconsolidated sand, gravel, and clay like those found commonly in glaciated areas elsewhere, but also they include many undrained basins surrounded on all sides by solid rock. These basins, in the channeled scablands of the Columbia Lava Plateau, are the result of a peculiar set of conditions where glacial melt water vigorously eroded the lava bedrock. In the northern part of the county, peat occupies shallow depressions which originated through irregular deposition of sand, gravel, and clay by the waning continental ice. Other basins, along the sides of the upper Spokane Valley, such as Newman Lake, Liberty Lake, and Saltese Marsh resulted from the damming of tributary streams at their mouths by sand and gravel deposited during rapid aggradation of the Pleistocene stream in Spokane Valley.

[3] See also several other papers by Bretz, listed in Bibliography and index of geology and mineral resources of Washington: Washington Div. Geology Bull. 35, p. 19-20, 1939.

Stevens County

Stevens County is immediately west of Pend Oreille, the northeasternmost county in the state. It lies entirely within the Okanogan Highlands physiographic province, and is characterized by a series of parallel mountain ranges and broad valleys which trend north and south. The crest of the Calispell Mountain Range is at the eastern edge of the county, west of which are the Colville-Chamokane Valley, then the Huckleberry Mountain Range, and, at the western border of the county, the Columbia-Kettle River Valleys. In addition to these four physiographic divisions there are two others—the Spokane River Valley at the southern boundary of the county, and the Spokane Plateau, north of the Spokane River.

The Calispell Mountain Range, also known as the Chewelah Mountains or Pend Oreille Mountains, forms the divide between the Pend Oreille (Clark Fork) River on the east and the Colville-Chamokane and upper Columbia Valleys on the west. This range extends southward from the Canadian boundary at the forty-ninth parallel to the southern part of the county, where it merges with the Spokane Plateau. The highest peak is Abercrombie, whose top is at 7,308 feet, but the average elevation along the summit of the range is about 5,000 feet. The western slope of the mountains is traversed by numerous deeply cut tributaries to the Colville and Columbia Rivers. The range is made up of metasedimentary and intrusive igneous rocks. Erosional activity of the Cordilleran ice sheet has modified the surficial features of all but the highest peaks, and depositional phases of the glaciation are represented by silt, sand, and gravel fillings in the valleys.

The Colville-Chamokane Valley extends through the center of the county from the Columbia River at the north to the Spokane River at the south, a distance of about 80 miles. The northern three-fourths of the valley slopes northward an average of 6 feet per mile and is occupied by the Colville River, a small sluggish stream which flows in a nearly flat-floored valley 1 to 3 miles wide. The southern portion of the valley slopes southward about 12 feet per mile and is occupied by Chamokane Creek, which enters the valley from the west near Springdale, only 1 mile from the point where the headwaters of the Colville River enter the valley from the east. Near its mouth Chamokane Creek has a narrow, steep-sided channel deeply incised in a broad, nearly flat-floored valley, but farther north to the point where it enters the valley it is in a channel only slightly entrenched. The Colville-Chamokane Valley has been deeply filled with glacial debris, but much of the surface is veneered with Recent sand and silt alluvium.

The Huckleberry Mountains are steep and have sharp ridges. The highest point, at 5,814 feet, is an unnamed peak near Stensgar Mountain, but the average elevation of the crest is about 4,500 feet. The Columbia River, at the western foot of the mountains, is at the 1,289-foot contour, whereas, east of the mountains, the Colville-Chamokane Valley averages 400 feet higher. Small tributaries of these streams have cut deeply into the mountains, and the lower valleys of these tributaries are filled with glacial drift. The highest peaks rose above the Pleistocene ice sheet, but the lower slopes were severely eroded by the ice. The rocks cropping out in the range comprise a wide variety of igneous, metamorphic, and sedimentary formations.

The Columbia-Kettle River Valleys form the entire western boundary of the county. The Columbia flows southwestward from the Canadian boundary near Northport to the mouth of the Kettle River, and thence southward to the mouth of the Spokane River, at the southwestern corner of the county. The valleys of both the Columbia and the Kettle Rivers are characterized by discontinuous terraces at various altitudes, up to about 2,000 feet, on both sides of the valleys. Most of the terraces are about 1 mile wide, but some are more than 2 miles. The material in the terraces is silt, sand, and gravel which accumulated in ponded water during glacial time. Some of the lower terraces which previously were exposed are now covered by Franklin D. Roosevelt Lake, the backwater from Grand Coulee Dam. The lake surface is at 1,289 feet when the reservoir is full, and it extends along the full length of the Columbia River Valley in Stevens County and for one-third the length of the Kettle River Valley. The lake varies in width from ¼ mile at the north to an average of 1 mile at the south.

The Spokane River Valley is similar topographically to the valleys of the Columbia and Kettle Rivers. The lower part of the valley is occupied by an arm of Franklin D. Roosevelt Lake, and the upper part by two other power-dam reservoirs.

The Spokane Plateau is a northern extension of the Columbia Lava Plateau. It comprises three isolated areas in southern Stevens County, the largest area being in the center and extending about 15 miles north from the Spokane River. The plateau is underlain by flows of the Columbia River basalt, which, however, are covered in many places by glacial debris. The surface has an average altitude of about 2,200 feet and is level to undulating except where interrupted by low, vertical cliffs adjacent to streams.

Topographically, the county has been well prepared for the accumulation of peat, both by glaciation and by postglacial events. All but the highest peaks were covered by ice. As the ice advanced it disrupted the pre-existing drainage pattern, and as it retreated it left a large amount of sand, gravel, and silt on the lower slopes and in the valleys. The surface of the glacial drift was irregular and contained shallow depressions, many of which still remain. Postglacial processes have resulted in other depressions in which peat has formed. Examples are found in the northern part of the county, where overburdened tributary streams have dumped their loads in alluvial fans, forming a succession of dams across the main courses of Cedar and Deep Creeks. The rate of dam-building has exceeded the erosive powers of the main streams, so the basins behind the dams have been maintained and peat has accumulated.

Thurston County

Thurston County, in the central part of western Washington, has an area of 719 square miles. The north boundary is indented by four long inlets at the south end of Puget Sound. Most of the county is a region of prairie and rolling lowland, but hilly to mountainous terrane adjoins the lowland on the south and west.

In plan view the lowland is funnel-shaped, having a narrow apex near the southwest corner of the county and broadening to the northeast, where it crosses into Pierce County, the surface being interrupted only by the Nisqually River Valley at the boundary common to the two counties. The land is mostly less than 500 feet above sea level. It slopes gently to the west and north, breaking off sharply in 100-foot bluffs along the shores of Puget Sound and in 100- to 200-foot bluffs bordering the Nisqually River Valley. The latter river, together with the Deschutes River, Woodward Creek, and Woodland Creek, flows northwestward to Puget Sound; whereas the Black River and Scatter Creek drain southwestward into the Chehalis River, which barely cuts the southwestern corner of the county. On the lowland are displayed most of the topographic features typical of continental glaciation—outwash plains, moraines, eskers, drumlins, and kettles. The plains are built up largely of outwash gravel, with a mantle of sand and black silt, in places peculiarly mounded. The gravels are so permeable that rain water is carried away chiefly underground, and surface streams are few and small. The moraines, eskers, drumlins, and kettles give undulating and pitted surfaces on areas of glacial till associated with minor amounts of sand and gravel. These are the areas where most of the peat and most of the numerous lakes in the county are found.

Foothills extend westward from the Cascade Mountains to form a hilly and mountainous belt along the eastern part of the south border of the county. These hills descend from more than 2,900 feet at the east to about 500 feet in the vicinity of Bucoda. The Skookumchuck River and the headwaters of the Deschutes River have dissected the Tertiary sandstones, shales, and volcanic rocks to produce steep, but not precipitous, hills.

The northeasternmost extension of the Willapa Hills covers 14 square miles south of the Chehalis River in the southwestern corner of the county. They rise from 80 feet, at river level, to a high point of 700 feet.

The Black Hills comprise an area of 112 square miles in western Thurston County, north of the Chehalis River. Although these hills reach northward to the southern tip of Puget Sound, all but a very small amount of the drainage is to the south, by way of a complex dendritic network of tributaries to the Black River and other Chehalis River tributaries. Capitol Peak, the highest point, reaches an altitude of 2,667 feet. Bedrock is of Tertiary volcanic rock, sandstone, and shale, but the lower slopes marginal to the lowlands are veneered with glacial drift.

Peat is found in almost all areas where there are deposits of glacial outwash or till, but more particularly in the till areas. This localization of peat in areas of till has resulted from a greater abundance of depressions there and from the relative impermeability of the till as compared to the glaciofluvial deposits. One body of peat, in a small flat-bottomed valley tributary to the Skookumchuck River, is south of the southernmost (Bretz, 1913) till area. The depression in which it lies was formed during glacial time, when a tremendous quantity of sand and gravel derived from the melting ice was poured into the

Skookumchuck River, aggrading its valley and blockading the tributary.

Whatcom County

Whatcom County is bordered on the west by Puget Sound, the north by Canada, the east by the crest of the Cascade Mountains, and the south by Skagit County. More than 85 percent of the county is mountainous, there being only a small area of lowlands in the northwestern corner, north of Bellingham. Most of the peat is restricted to this lowland area, but it is abundant enough there, covering an estimated 10 percent of the land surface, to give Whatcom County greater peat acreage than any other county in the state.

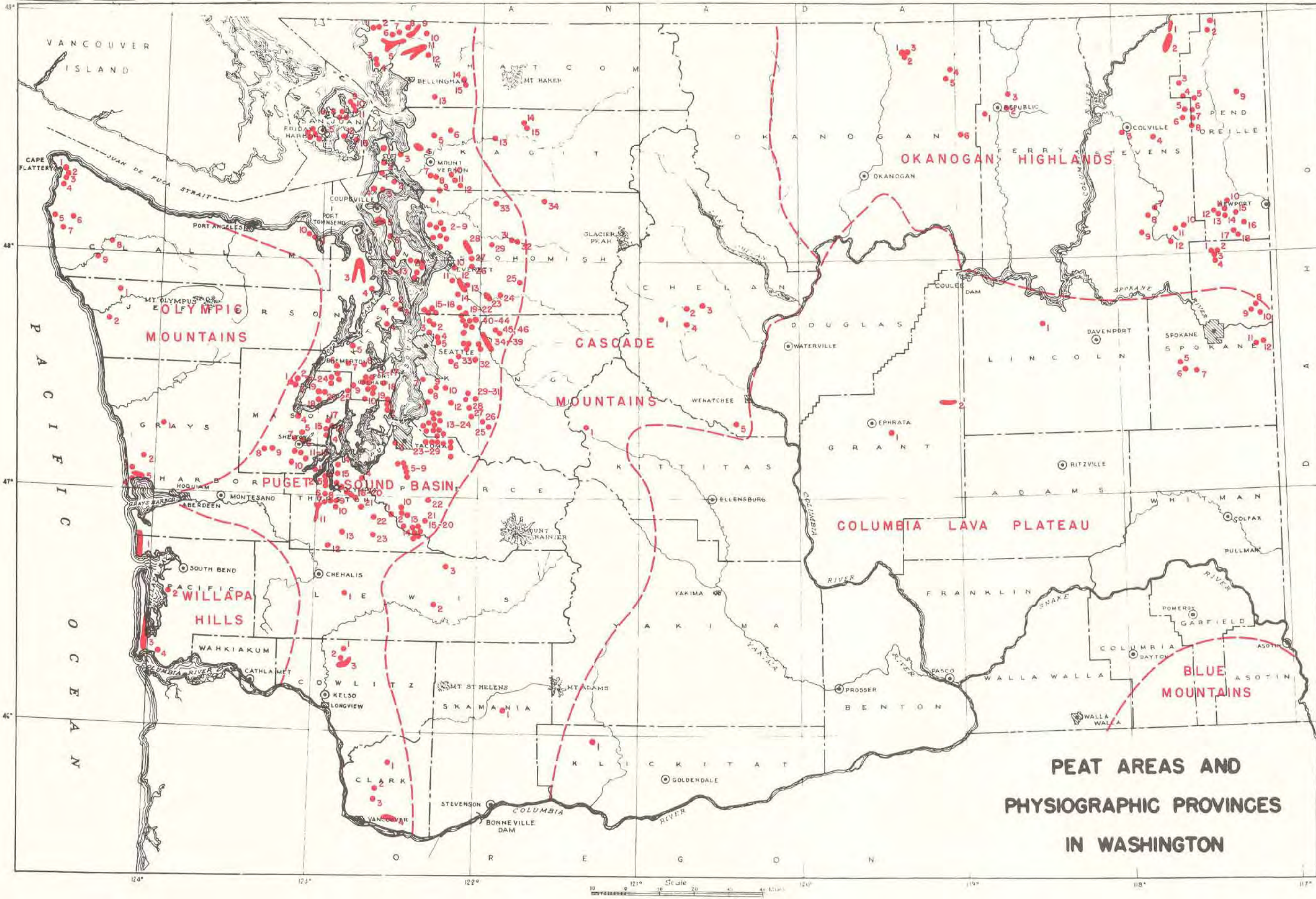
The mountainous area extends westward from the 5,000- to 8,000-foot Cascade crest through all of the eastern and central parts of the county, including 10,750-foot Mount Baker, to Puget Sound in the area south of Bellingham. North of Bellingham the mountains do not reach to the sound but are abruptly terminated at the western foot of Squalicum, Anderson, and Sumas Mountains, which extend northeast from Bellingham to the town of Sumas at the Canadian boundary. The southwestern part of the region has high relief. Chuckanut Mountain rises to 2,385 feet in a distance of only 2 miles from Samish Bay, and the relief increases eastward, where the mountains are extremely rugged and for the most part inaccessible by road. The Skagit River drains the area east of Mount Baker, and the Nooksack River drains the area to the west.

The lowlands are entirely covered by Pleistocene sand, gravel, clay, and unassorted glacial debris, and Recent alluvium, except for a few small isolated outcrops of old rock. This is a region of low relief, more than half of the area lying below the 140-foot contour and being a series of broad flats, for the most part developed as features of the flood plain of the Nooksack River. The lowlands include three small areas of somewhat greater relief given by rounded hills marginal to the flood plain. These are the hills east of Blaine, rising to 500 feet, the hills west of Ferndale, rising to 380 feet, and the hills north of Bellingham, rising to 320 feet.

All the lowland area was covered by Pleistocene continental ice, which during its advances and retreats deposited till and stratified drift to a depth of as much as 615 feet (Glover, 1935, p. 28). Most of the depressions in which peat has accumulated are very shallow. The low hills are made up of till, and the bogs there are comparatively small, whereas the larger bogs are situated on the Nooksack flood plain in glacial outwash and Recent alluvium left by shifting streams in latest glacial and postglacial times. Peat in the mountainous portion of the county is found in the Nooksack Valley in areas of poor drainage developed through aggradation of the valley incidental to major drainage changes of probable glacial origin.

PEAT AREAS

Boundaries of physiographic provinces as shown on the map are approximate only.



PEAT AREAS AND PHYSIOGRAPHIC PROVINCES IN WASHINGTON

DISTRIBUTION BY COUNTIES

The distribution by counties arranged in the order of total acreage of peat in each is shown in the table below, and the largest area and the deepest area in each county are included. This table indicates in a general way the relative importance of the deposits in the counties. Detailed information in regard to the deposits in each county is given later in this chapter. Of the 39 counties in the state, 28 are known to contain peat deposits. Of these 28 counties, 18 are west of the main ridge of the Cascade Mountains.

The peat deposits by counties

County	Total area of all deposits (acres)	Largest deposit (acres)	Deepest deposit (feet)
1. Whatcom	6,616	2,450	48+
2. Snohomish	6,069	1,975	47+
3. Pacific	5,037	3,500	11
4. King	3,373	535	63
5. Thurston	2,978	1,455	50+
6. Stevens	2,746	308	27
7. Jefferson	2,730	2,605	48+
8. Spokane	2,713	1,200	50+
9. Mason	2,628	500	36+
10. Island	1,946	792	50
11. Pend Oreille	1,941	528	39+
12. Pierce	1,890	262	47
13. Grays Harbor	1,870	479	12
14. Grant	1,415	1,415	16
15. Skagit	1,139	616	50+
16. Clark	1,064	440	27
17. Clallam	1,021	400	24
18. Kitsap	815	137	40+
19. Cowlitz	736	700	12
20. Lewis	691	542	42
21. San Juan	539	240	43
22. Okanogan	283	262	20
23. Chelan	186	180	39
24. Klickitat	50	50	4
25. Ferry	31	20	15
26. Kittitas	25	25	6
27. Lincoln	10	10	13
28. Skamania	5	5	9

The largest deposits (of more than 600 acres) in the state are given in the order of size in a table on this page. The largest area shown in this table is not strictly one area (map, fig. 118), but it is conveniently considered as one because the areas are close together, the hard land between them is low, and the depressions in which they lie have a similar origin. The same is true of the second deposit in the table. It will be noted that 11 of the 14 deposits shown in this table are west of the Cascades. In this connection it may be recorded that the total peat area west of the main ridge of the Cascades is 41,123 acres and the total east of that ridge is 9,400 acres.

The deepest deposits in the state (40 feet or more) are shown in a table on this page. The + sign in this table means that the bottom of the deposit was not reached with the peat borer, and the total depth is therefore not known. The word "soft" following the + sign means that the peat at this depth could be easily penetrated, but the equipment available did not permit deeper boring. The word "compact" following the + sign indicates that the peat at that depth was too compact to be penetrated farther with the peat borer.

Largest peat deposits (of more than 600 acres)

Deposit	County	Area (acres)
1. Peninsula	Pacific	3,500
2. Chimacum	Jefferson	2,605
3. Wiser Lake	Whatcom	2,450
4. Frye Marsh	Snohomish	1,975
5. Grayland	Grays Harbor and Pacific	1,946
6. Custer	Whatcom	1,636
7. Black River	Thurston	1,455
8. Crab Lake	Grant	1,415
9. Northwood	Whatcom	1,230
10. Saltese Marsh	Spokane	1,200
11. Snohomish Valley	Snohomish	920
12. Newman Lake (south end)	Spokane	730
13. Silver Lake	Cowlitz	724
14. Lake Cassidy-Lake Martha	Snohomish	623
15. Burlington	Skagit	616

Deepest peat deposits (40 feet or more)

Deposit	County	Depth (feet)
1. Covington	King	63 soft
2. Mercer Slough	King	51+ soft
3. Big Lake	Skagit	50+ soft
4. Hicks Lake	Thurston	50+ compact
5. Little Trout Lake	Spokane	50+ compact
6. Cranberry Lake	Island	50
7. Mosquito Lake	Whatcom	48+ soft
8. Chimacum	Jefferson	48+ compact
9. Paradise Lake No. 2	Snohomish	47+ compact
10. Silver Lake	Pierce	47
11. Otter Lake	King	46
12. Maple Bowl	Thurston	44
13. Ames Lake Creek	King	44
14. Beaverton Valley	San Juan	43
15. Belmore	Thurston	42+ soft
16. Chain Hill	Thurston	42
17. Davis Lake	Lewis	42
18. Cottage Lake No. 1	King	41
19. Gurley Creek	Kitsap	40+ soft
20. Carpenter Lake	Kitsap	40
21. Miller Lake No. 1	Kitsap	40

It will be noted that 20 of the 21 deposits listed in this table are west of the Cascade Mountains. There is no consistent relation between large size and great depth. The Peninsula deposit in Pacific County (area 3,500 acres) has a maximum depth of only 11 feet, and the Grayland deposit in Pacific and Grays Harbor Counties (area 1,946 acres) has a maximum depth of only 7 feet. The Little Trout Lake deposit in Spokane County has an area of only 14 acres, but its depth is more than 50 feet. The Mosquito Lake deposit in Whatcom County has an area of only 16 acres, but its depth is more than 48 feet. Some large deposits, however, are deep. The Wiser Lake deposit in Whatcom County has a total area of 2,450 acres and a maximum depth of 30 feet. The Mercer Slough deposit in King County (area 535 acres) has a maximum depth of more than 51 feet.

CHELAN COUNTY DEPOSITS

Fish Lake peat area

The Fish Lake area (180 acres) borders the west end of Fish Lake and is in secs. 16 and 21, T. 27 N., R. 17 E. (map, fig. 3), on the eastern slope of the Cascade Mountains. It lies about 1 mile northeast of Lake Wenatchee and about 18 miles northeast of Stevens Pass. State Highway 15C extends near the peat area, and in 1949 the area was accessible from the north and also from the west from a graveled road.

Fish Lake owes its origin to glacial activity. Russell (1900) says, "This lake is shallow and is retained mainly by a lateral moraine of the Wenache [Wenatchee] glacier and by irregular heaps of debris, which in part have the characteristics of kames."

The 1,900-foot contour (Chiwaukum quadrangle, U. S. Geological Survey) is close to the margin of the peat area on the north, west, and south sides. A steep slope, rising several hundred feet, begins not far from the north side, but the land on the south and west sides is flat. An intermittent stream flows into the bog from the north, and other intermittent streams flow down the steep slopes and into the north side of the lake. A stream flows from the south side of the lake into the Wenatchee River. A few miles west of the peat area, at an elevation of 1,990 feet, the mean annual precipitation is about 38 inches, less than 15 percent of which occurs during the growing season (Hansen, 1941a). These facts and the observations made on the western portion of the peat area indicate that the water level in the area is considerably higher in spring than it is in summer.

This peat area, shown on the Chiwaukum quadrangle as marsh, comprises brushy swamp, sphagnum bog, wet meadow, and a floating mat of vegetation. A strip of brushy swamp 100 feet or more in width occupies the margin of the area on the north, west, and south sides. The brushy plants and the small trees which grow with them form a dense growth, and many low herbaceous plants grow among them. In late July 1949 this strip was wet but there was no standing water in it. Drift material indicated, however, that the area had been flooded.

The sphagnum bog lies next to this brushy strip but is not continuous all around the peat area. The *Sphagnum* moss in the bog is living and is accompanied by an abundant growth of low bog herbs, with a very few low bog shrubs scattered here and there. A few stunted coniferous trees are scattered over the sphagnum bog and the adjoining meadow.

This sphagnum area, which furnishes rather firm, though wet, footing, merges into a very soft wet meadow on which the footing is less firm. The meadow is characterized by sedges and other herbaceous plants among which mosses other than *Sphagnum* grow. This meadow merges into a floating mat of vegetation, composed of sedges and similar plants, which extends eastward to the zone of water lilies at the margin of the lake.

The footing becomes less firm as one walks from the meadow to the mat, and progressively less firm toward the lake. One man in hip boots walked out to within about 300 feet of the lake. He estimated that the mat sank 3 feet under his weight.

The strata of peat and also the muck underlying the brushy swamp are shown in the profile (fig. 3). The sedi-

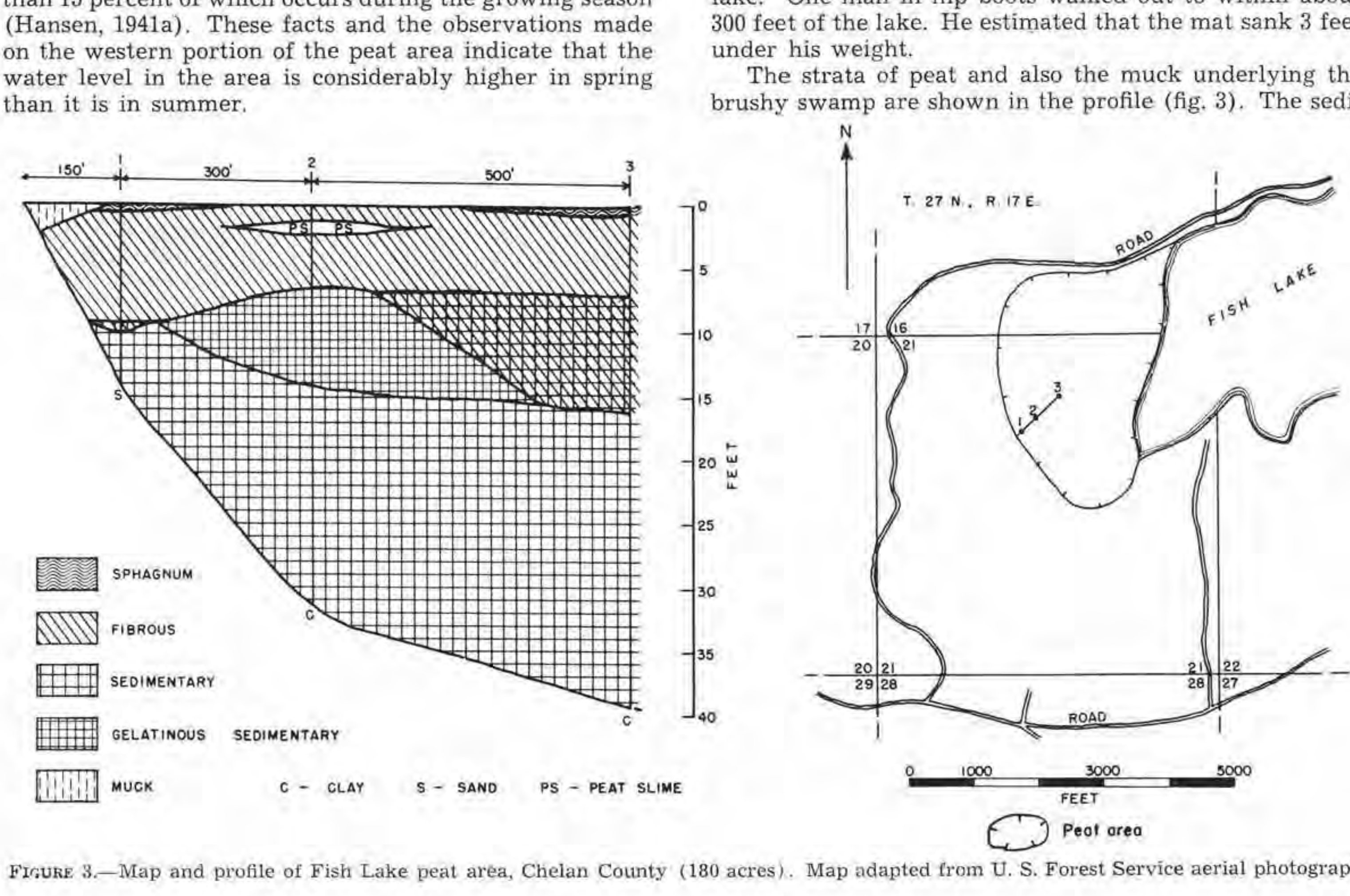


FIGURE 3.—Map and profile of Fish Lake peat area, Chelan County (180 acres). Map adapted from U. S. Forest Service aerial photograph.

mentary peat is wet and becomes progressively more watery toward the lake. Its color varies between olive green and olive brown. Two pH determinations on it were 6.2 and 6.3, indicating that it is rather weakly acidic. The layer of gelatinous sedimentary peat shown at hole 2 is yellow to yellow green in color and has the consistency of soft jelly. Its pH (5.0) indicates that it is considerably more acidic than the main body of sedimentary peat which lies under it. Most of the fibrous peat in this area consists of the remains of sedges, but some of it near the margin is very coarse, and some of it farther toward the lake is composed of very fine fibers and is felty in character. Nearly all of it is very wet. The pH is 5.2. The sphagnum peat is of good quality, but there is too little of it to be of any importance. Its pH in 4.5. The muck which underlies the brushy swamp consists of mineral soil, washed in from the adjoining hard land, and organic matter resulting from the decay of plants that grew in the margin of the lake or in the swamps as the lake margin was filled. The greenish color of the greenish-gray clay on which the muck rests possibly may be due to the presence of iron (ferrous) salts.

Hansen (1941a) bored a hole in the northern part of this peat area. He found 6.5 meters (21 feet four inches) of peat with silt underlying it. The upper 3 meters (9 feet 10 inches) was fibrous sedge peat, and the lower 3.5 meters (11 feet 6 inches) was limnic (sedimentary) peat. Particles of pumicite were mixed through the upper 29 inches of the sedimentary peat.

No evidence of any attempt to utilize the peat of this area was seen. The surface is so soft and wet that any road built on it would undoubtedly sink into the peat. It seems evident that any equipment used in removing peat would have to be afloat. Peat has been removed from some very watery areas in western Washington by the use of a dragline or a clamshell operated from a barge.

Winton peat area

The Winton peat area (3 acres) is in sec. 17, T. 26 N., R. 17 E. (map, fig. 4), 0.7 mile north of Winton, a station on the Great Northern railroad. It borders U. S. Highway 10A about half a mile south of the junction of the Lake Wenatchee road with this highway. It is a small part of a larger sedge meadow of 40 acres or more in area. Some of the meadow is utilized as a hayfield. The flat on which it lies is underlain mostly by clay, but there is some sand. Steep slopes border the flat on the east and west. Ditches on the peat deposit and the flat provide drainage to the Wenatchee River by way of Mason Creek.

The profile (fig. 4) shows muck, fibrous peat, a mixture of fibrous peat and sedimentary peat, a ½-to-2-inch layer of white and tan pumicite, one layer of clay, and one of sand and clay. The deposit rests on clay and sand.

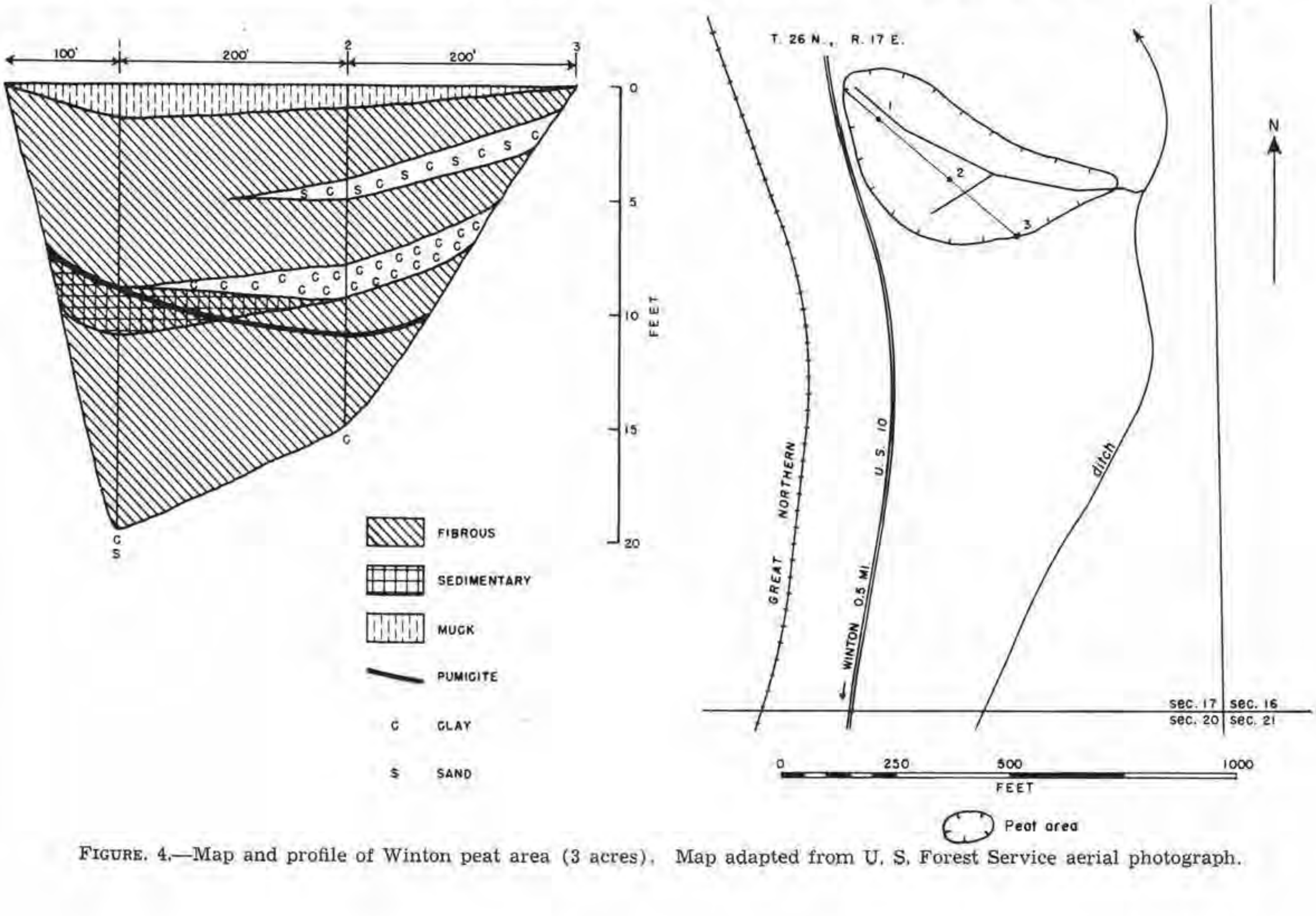


FIGURE. 4.—Map and profile of Winton peat area (3 acres). Map adapted from U. S. Forest Service aerial photograph.

Merritt peat area

The Merritt peat area (1 acre) is in the NE¼ sec. 6, T. 26 N., R 16 E., a few hundred feet south of U. S. Highway 10, about 3 miles west of Merritt. It is a small sedge meadow with some *Dulichium* and some water lilies, and is surrounded by flat land on which hardhack grows. The area evidently is flooded in wet weather. The one hole bored near the center of the area shows 5 feet of fibrous peat and 1 foot of mixed fibrous peat and sedimentary peat resting on sand.

Beehive Mountain peat area

The Beehive Mountain peat area (1½ acres) is in the Wenatchee National Forest in sec. 12, T. 21 N., R. 19 E., about 7 airline miles southwest of Wenatchee. It is shown as marsh on the Wenatchee quadrangle. The area is reached by driving up the Squillchuck Road from Wenatchee and turning off on a road to the west, the total distance being about 9 miles. The elevation of the summit of the mountain is 4,576 feet. Hansen (1939) gives the elevation of the peat area as 4,200 feet.

The depression in which the peat has formed apparently owes its origin to the blocking of drainage by a landslide (Hansen, 1939). No evidence of glaciation was seen in the vicinity. There is no surface drainage from the peat area, but there is drainage from the vicinity into Squillchuck Creek, which flows into the Columbia River near Wenatchee.

The peat area is mainly a sedge meadow with an abundant growth of *Hypnum* moss among the sedges. In some places vegetation which is characteristic of swamps occurs. The materials found by boring are hypnum peat, fibrous peat, sedimentary peat, muck, diatomite, pumicite, and mixtures of diatomite and muck, and of fibrous and sedimentary peat. The fibrous peat is composed largely of the remains of sedges and *Hypnum* moss. The muck probably contains only a relatively small amount of organic matter. The pumicite is white and occurs in a layer ½ inch to 2 inches thick. The shrubs and trees around the margin of the peat area are mostly hardhack, western dogwood, and trembling aspen. The forest around the area is very open.

Some peat was removed from the area and sold prior to 1949. Later, probably in 1953, the entire peat deposit was destroyed in making a large excavation for an irrigation reservoir.

Goose Creek area

A small marsh is shown on the Chiwaukum quadrangle, in secs. 17 and 18, T. 27 N., R. 18 E. The part of it that was examined lies in sec. 18. It has forest on both sides, and a clear stream flows through it. Two holes bored in the marsh showed relatively little peat. The deeper hole shows the following section from top to bottom: 1 foot of fibrous peat, with a thin layer of pumicite in the middle; 1 foot of diatomite; 6 inches of clay; 18 inches of pumicite; 1 foot of fibrous peat; 1 foot of mixed fibrous and wood peat; and 3 feet of pumice underlain by sand and clay. The other hole shows from top to bottom: 1 foot of muck; 2 feet of diatomaceous muck; 9 inches of fibrous peat; 3 inches of pumicite; 1 foot of mixed fibrous and wood peat; 1 foot of mixed fibrous and wood peat and pumice; and pumice which could be penetrated with the peat borer to a depth of only 1 foot.

Other areas shown as marshes on the Chiwaukum quadrangle

A marshy area of perhaps 250 acres that may contain peat lies along Big Meadow Creek about 4 miles north of Lake Wenatchee. It has not been investigated. A small area on Deep Creek at its junction with another stream in sec. 20, T. 27 N., R. 18 E. was observed by driving across it on the road that extends down Deep Creek Valley. This area is a meadow covered with a luxuriant growth of sedges. It is continuous with the marsh area shown at the head of Clear Creek. The whole meadow probably contains peat, but no digging or boring was done in it.

CLALLAM COUNTY DEPOSITS

Wessler peat area

The Wessler peat area (23 acres) is in secs. 25, 26, 35, and 36, T. 31 N., R. 15 W. It is about 2 miles northeast of the nearest point on the shore of Ozette Lake, and about 7 miles in a direct line from the Pacific Ocean. It is reached by driving west about ½ mile on a private road from the Clallam Bay-Ozette road.

It is bordered partly by low hills and partly by flat land. The deposition of silty and gravelly glacial drift has been the main factor in the formation of the depression in which the peat has been formed. The hilly part of the region immediately surrounding the bog is mapped in the Soil Survey of Clallam County (Smith et al., 1951) as Astoria, Hoko, and Sekiu soils, undifferentiated (0 to 30 percent slope). These soils are discussed in the description of the Ahlstrom peat area on page 42. The flat portion of the area bordering the bog is mapped in the Survey as Reed clay (0 to 1 percent slope). Of this soil type the Survey says, "The widely distributed areas of this inextensive soil occur on low-lying stream bottoms in the zone of high rainfall. The swampland associate of Chehalis loam, the soil is developed on fine sediments laid down at flood stage from slow-moving or still backwaters." Caution must be observed in applying this general statement regarding the manner of deposition of this soil to the local deposit bordering this peat area, but the statement probably gives an essentially correct picture.

This peat area is a very wet sphagnum bog, on a portion of which a commercial cranberry bog of about 4 acres has been established. Trout Creek, which flows across the unimproved portion of the bog and into Ozette Lake, passes close to one corner of the commercial cranberry planting. Ditches into the creek provide sufficient drainage for the commercial bog, but in 1950 there was not sufficient drainage to remove surplus water from the unimproved portion of the bog, and water stood on it in some places.

The bog is covered with the usual sphagnum-bog vegetation of low shrubs and herbaceous plants, though in the wetter places there are some species that are characteristic of swamps. Mosses form a dense growth on the surface among the shrubs and herbs. *Sphagnum* is the most abundant moss, but *Hypnum* and other mosses also occur. The trees are small cedar, hemlock, spruce, and crab apple. Around the margin there is a shallow depression of the type that is usually called a marginal ditch in sphagnum-bog descriptions. It has a dense growth of crab apple trees, among which grow several species of swamp shrubs and herbs. Beyond the marginal ditch there is coniferous forest on gentle slopes or flat land.

The peat in this bog is considerably deeper than that found in other bogs of the state which occur near the ocean, as will be seen by comparing its profile (fig. 5) with those of the Forks bog in Jefferson County (fig. 35) and the numerous bogs near the ocean in Grays Harbor and Pacific Counties (figs. 18, 19, 20, 118, and 123).

The sphagnum, which reaches an extreme depth of 3 feet near the north border of the bog and thins out near the center, is light brown and raw near the surface but is disintegrated and somewhat darker at the bottom of the layer. The living *Sphagnum* at the surface has the usual high acidity. Its pH at hole 2 is 3.7. The peat slime which extends entirely through the profile is brown. The fibrous peat is brown to dark brown, and much of it is decomposed. Its pH at a depth of 1 foot in hole 4 is 4.0. The wood peat, which is mostly mixed with the fibrous peat, was probably formed from wood washed in from the nearby slopes. The muck is gray.

The commercial cranberry bog which was established in 1938 or 1939, produces an abundance of berries of good quality. It is operated by the owner, who lives nearby.

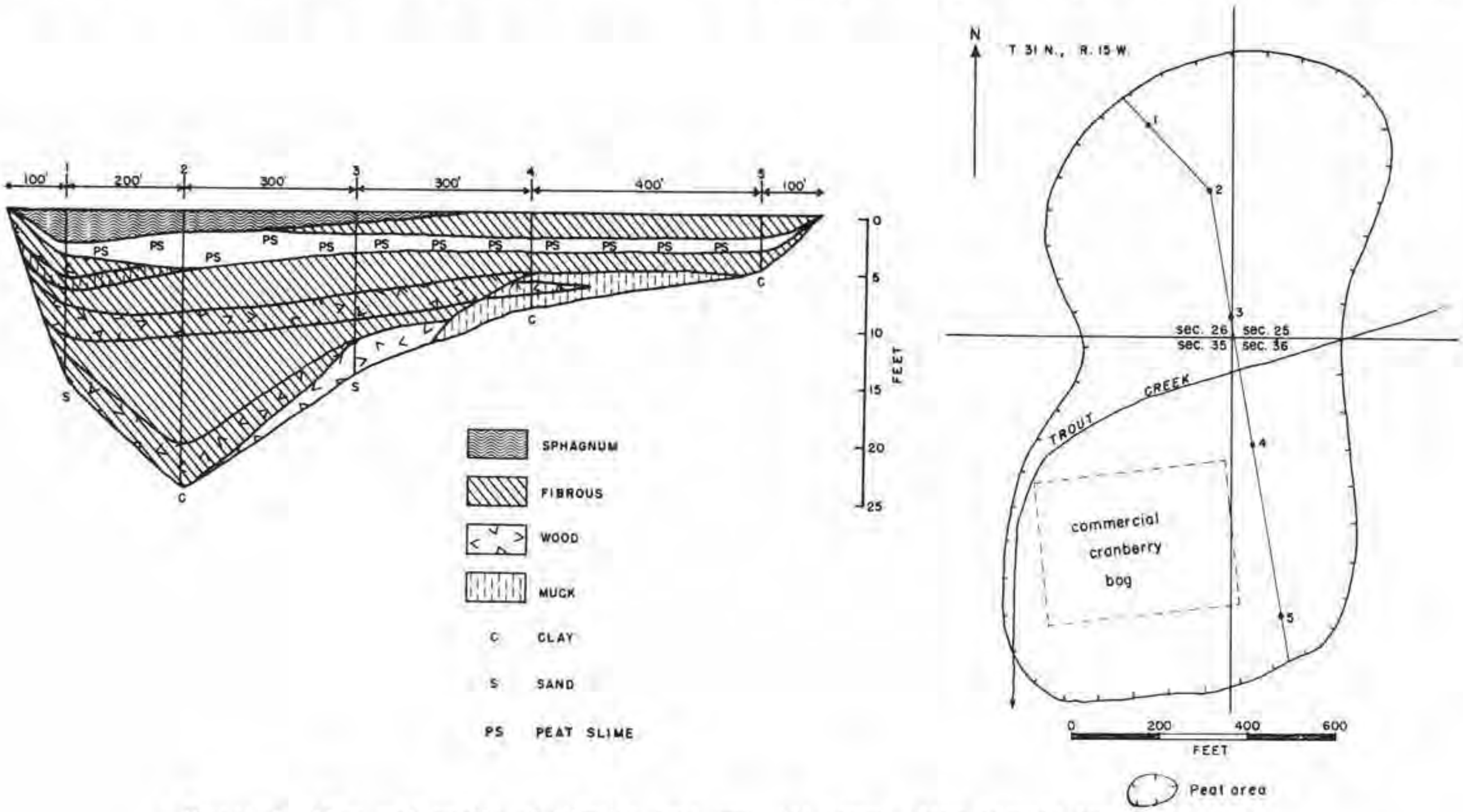


FIGURE 5.—Map and profile of Wessler peat area (23 acres). Map adapted from field sketch.

Tyee peat area

The Tyee peat area (about 5 acres) is a sphagnum bog situated in the SW¼SE¼ sec. 34, T. 30 N., R. 13 W., less than ½ mile southwest of the village of Tyee, which is on U. S. Highway 101. It is about 16 miles in a straight line from the Pacific Ocean and about the same distance from the Strait of Juan de Fuca.

It is in the valley of the Soleduck River, probably about ½ mile north of the nearest point on that meandering stream. It occupies the floor of a depression about 60 feet deep in glacial drift. The steep slopes of the depression are covered with coniferous trees, and the region around the depression is comparatively flat land on which the coniferous forest has been logged.

The bog has the usual growth of sphagnum-bog shrubs and herbaceous plants. Its surface is covered with living *Sphagnum* and *Hypnum* moss which form numerous hummocks. The scattered small trees are hemlock, spruce, Douglas fir, and cascara.

This very thin accumulation of peat in a depression which has no surface drainage suggests subterranean drainage. Utilization of this bog is obviously improbable because of its small size, the shallowness of the peat, and the steepness of the sides of the depression.

One hole bored near the center shows 3½ feet of peat, including 2 feet of brown wet sphagnum, the lower 6 inches of which is disintegrated, and 18 inches of brown disintegrated fibrous peat under which is tan-colored clay.

Fletcher peat area

Several statements by reliable persons who lived in the vicinity many years ago, some of whom still live there, indicate that there is a peat area of probably 10 acres or more on the old R. W. Fletcher ranch. These statements agree well and suggest the following: The bog is north of the Soleduck River and is about 2 miles west of the bridge on which U. S. Highway 101 crosses the river. Formerly, it was a sphagnum bog on which the settlers picked wild cranberries. There was an abundant growth of *Sphagnum* moss on it. The trees on it were scrub pine and were small in the central portion of the bog but larger at the margin. At its borders the bog merged into the dense coniferous forest. There was a clearing around the ranch buildings, but it and the bog are now so overgrown with trees and brush that it is difficult to find. The bog was not examined during the investigations on which this bulletin is based.

Ahlstrom peat area

The Ahlstrom peat area (about 10 acres) is a shallow sphagnum bog in Ahlstroms Prairie, in the SW¼ sec. 25, T. 31 N., R. 16 W. It is less than a mile from the Pacific Ocean and about 2 miles west of Ozette village, which is at the north end of Ozette Lake. The road from Clallam Bay ends at Ozette village, and the bog is reached by an improved trail through the forest. This trail, which is passable for horses, extends to Cape Alava on the ocean shore. It is shown on a soil map which accompanies the Soil Survey of Clallam County, Washington (Smith et al., 1951) as well as on most other maps of the area.

The soil of the immediate region is mapped in the Survey as Astoria, Hoko, and Sekiu soils, undifferentiated (0 to 30 percent slope). These are characterized as lateritic soils which "have developed in place on bed rock and consolidated glacial drift." Of Sekiu clay the Survey says, "This inextensive soil, developed under swampy or Half Bog conditions, occupies very gentle slopes or flat areas and slight depressions in the western part of the county, as at the north end of Ozette Lake."

Ahlstroms Prairie and the trail from Ozette village to Cape Alava are shown on the Ozette Lake quadrangle (Grid Zone "G," Corps of Engineers, U. S. Army). Two other nearby prairies, which were not examined, are shown on the quadrangle. One is Rooses Prairie, and the other is unnamed.

The area of Ahlstroms Prairie is about 140 acres. Living *Sphagnum* is reported along the Cape Alava trail farther west than the Ahlstrom deposit. No information is available to indicate whether there is peat under this *Sphagnum*. A small slow stream flows across the peat and on northward across Rooses Prairie to the Ozette River, which flows into the ocean. The bog is shown as a marsh on the Ozette Lake quadrangle.

The low shrubs and herbaceous plants growing on this bog are, with one exception, those that are characteristic of sphagnum bogs in western Washington. The exception is a low species of gentian with whitish or yellowish flowers (*Gentiana Douglasiana*), which is common in this bog and also in Ozette bog only a few miles distant. This species is common in bogs in Alaska and on Vancouver Island, but so far as reported is not found farther south than the Ozette Lake region. A tall gentian (*G. sceptrum*) with blue flowers is also found in the Ahlstrom bog and Ozette bog. It occurs in many bogs in western Washington.

Two holes were bored in this peat just north of the trail. Hole No. 2 (8 feet deep) was on the west bank of the stream, and No. 1 (3 feet deep) was 500 feet west of No. 2. Hole 2 shows 9 inches of sphagnum at the surface. Under this is dark-brown decomposed fibrous peat down to the 4-foot level. In the next 2 feet wood peat is mixed with the fibrous peat. The bottom 2 feet is gray muck which rests on blue clay. Hole 1 shows 6 inches of raw sphagnum, 6 inches of decomposed sphagnum, and 2 feet of dark-brown decomposed fibrous peat which rests on gray clay.

Though sphagnum peat is found at both holes and living *Sphagnum* is abundant on the bog and is also found growing in the damp forest along the trail from Ozette to the prairie, it does not seem probable that either sphagnum peat or fresh *Sphagnum* in this area will be of any economic importance in the foreseeable future.

Ozette Lake peat area

Part of the Ozette Lake peat area is a sphagnum bog (probably about 30 acres) bordering the west shore of Ericsons Bay, which is an embayment of Lake Ozette. The bog is in sec. 8, T. 30 N., R. 15 W. There are low hills to the west of the bog, which is in the uncolored (treeless) area shown on the Ozette Lake quadrangle. A trail is shown on this map extending from a point a little south of the bog on the shore of Ozette Lake to Sand Point on the shore of the Pacific Ocean. The distance in straight line from the bog to the ocean is less than 2 miles. The soil of the region bordering the lake and the bog is shown on the soil map of Clallam County (Smith et al., 1951) as Astoria, Hoko, and Sekiu soils, undifferentiated (0 to 30 percent slope).

This bog was examined by Rigg in 1933, and the following observations are based on data recorded at that time. The bog begins at the lake shore just back of the zone of water lilies. The usual sphagnum bog shrubs and herbs are found here. Also present are the two species of gentian mentioned in the notes on the Ahlstrom peat area. There are some small dogwood trees, and the low herbaceous dogwood (*Cornus canadensis*) is also present. Near the border of the bog are cascara trees. No digging or boring was done.

Sooes River peat area

The Scoes River peat area (102 acres) is a shallow sphagnum bog in sec. 5, T. 32 N., R 15 W. (map, fig. 6). The western margin of the broad southern portion of the bog is about 450 feet east of the Sooes (Suez) River, and slightly more than half a mile from the shore of the Pacific Ocean. The eastern margin at the corresponding point is 270 feet west of the center of the Crown Zellerbach Corporation's private logging road to Neah Bay, 6 miles distant. The bog is in the Makah Indian Reservation and is accessible also by a short walk from an Indian Service road from Neah Bay. The bog is shown as Greenwood peat on the map of the Soil Survey of Clallam County (Smith et al., 1951). It is also shown as an uncolored (treeless) area on the Cape Flattery quadrangle.

The soil of the area surrounding the bog and extending from the river to the logged-off hills on the east is shown on the soil map as Reed clay (0 to 1 percent slope). This

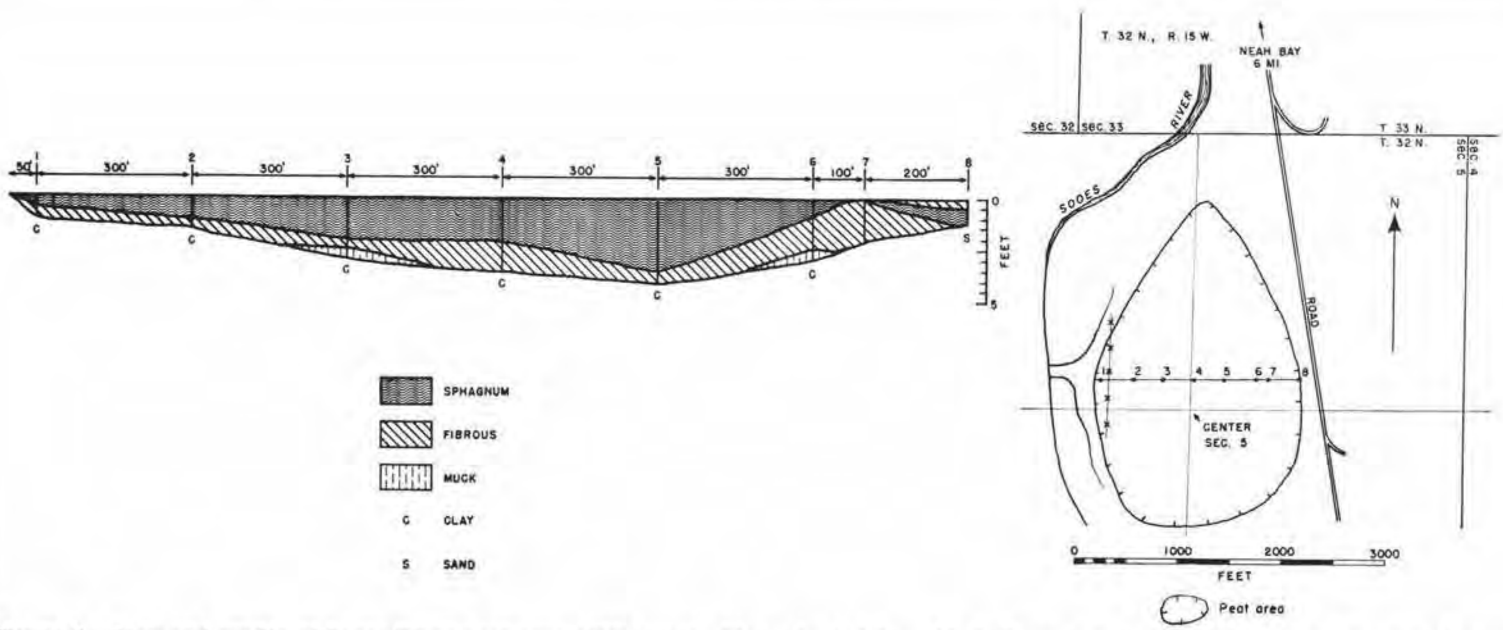


FIGURE 6.—Map and profile of Sooes River peat area (102 acres). Map adapted from U. S. Department of Agriculture soil map of Clallam County and Crown Zellerbach Corp. map.

soil type has been discussed under the description of the Wessler peat area on page 40. This strip of Reed clay, which is about half a mile wide on a line crossing the bog from east to west, extends north and south along much of the course of the river. It seems evident that the river has shifted its position on this flat in past times and that the shallow undrained depression in which the bog has developed is the result of this activity of the river.

The central portion of the bog has the usual flora of shrubs, and, in addition to the usual herbaceous bog plants, skunk cabbage is abundant. The small stunted conifers on the bog are hemlock, cedar, and spruce. *Sphagnum* moss, *Hypnum* moss, and feather moss are abundant, and all form numerous hummocks. The natural marginal ditch at the east margin has a dense growth of cedar, spruce, hemlock, crab apple, cascara, and salal. There is an open forest, partly logged, between the east margin of the bog and the Crown Zellerbach Corporation's road. The west margin of the bog has an open growth of cedar and spruce. The shrubs there are mostly Labrador tea and hardhack, among which sedges and rushes grow. The sphagnum at hole 2 is rather strongly acid (pH 4.0).

The profile (fig. 6) shows a relatively large proportion of sphagnum. This sphagnum is of good quality and is suitable for use by florists and gardeners. The geographical location, however, is such that the haul to centers from which such material is commonly distributed would be rather long. It seems probable, too, that less than half of the 102 acres in the bog has sphagnum deep enough and continuous enough to justify its utilization. The northwestern portion of the peat area, with some adjoining hard land, is enclosed by a fence and evidently has been used for pasturage.

Crown Zellerbach peat area

The Crown Zellerbach peat area (41 acres) is in the W½ sec. 33, T. 33 N., R. 15 W. (map, fig. 8). The Crown Zellerbach Corporation's private logging road to Neah

FIGURE 7.—Making a boring in Sooes River sphagnum bog.

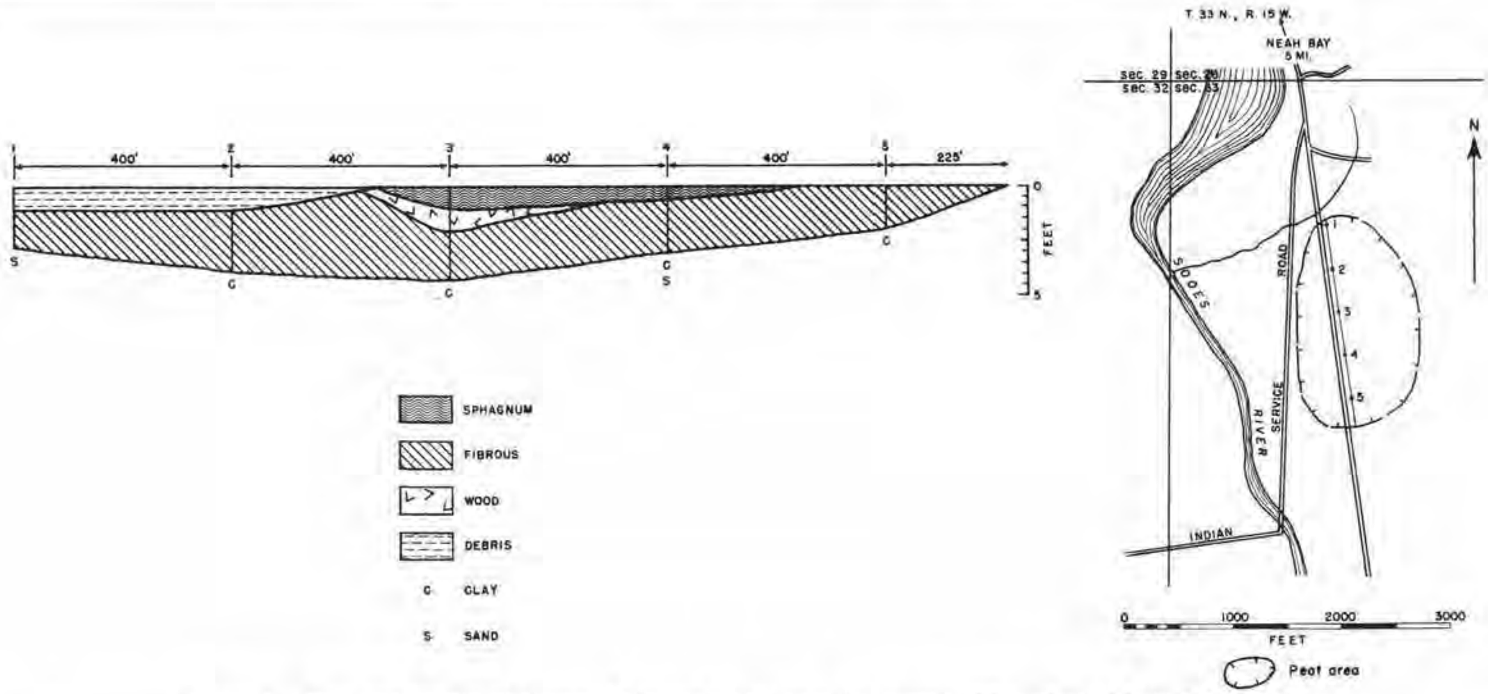


FIGURE 8.—Map and profile of Crown Zellerbach peat area (41 acres). Map adapted from field sketch.

Bay (5 miles) crosses the area from south to north. The peat area is in the Makah Indian Reservation, and an Indian Service road from Neah Bay extends close to its western border. It is in the flat area of Reed clay (Smith et al., 1951) and is about a mile north of the Sooes River peat area.

The depression in which this peat has developed was evidently formed by irregular deposition of sediments from slow-moving or still backwaters of the Sooes River. The peat area has been logged, and its surface is now covered with stumps and the general debris of logging, and with some young trees, swamp shrubs, and herbs. The peat is all fibrous except for some sphagnum peat at holes 3 and 4 and some wood peat at hole 3. It rests on clay and sand. The deepest peat (4 feet) is in hole 3. No evidence of attempts at utilization was seen.

Neah Bay peat areas

Five areas of Rifle peat are shown on the soil map of Clallam County (Smith et al., 1951) in the vicinity of the village of Neah Bay. The largest (about 250 acres) borders the village and is mostly in sec. 15, T. 33 N., R. 15 W. The village is on the shore of Neah Bay, which is a part of the Strait of Juan de Fuca. The other four areas are small, and all lie within about a mile of the village. They are covered mostly with a rather open but somewhat brushy forest of conifers and deciduous trees. The greatest depth of peat found by digging and boring in the large area is 3 feet. One hole 3 feet deep shows 2 feet of mixed fibrous and wood peat underlain by 1 foot of peat slime. Another hole, 100 feet distant, shows 3 feet of mixed fibrous and wood peat underlain by 1 foot of muck. No attempt at utilization of the peat in these five areas was apparent.

Waatch tidal marsh area

The Waatch tidal marsh area (approximately 400 acres) lies along the Waatch River in the Makah Indian Reservation from the vicinity of Neah Bay to the Pacific Ocean. It is mostly in secs. 15, 16, 21, and 22, T. 33 N., R. 15 W. The vegetation on it consists principally of salt-marsh plants, though a few salt-tolerant weedy species have been introduced in some places. There is an abundance of native salt grass present, and the area is used for pasturage. An Indian Service road and a Crown Zellerbach Corporation private logging road extend across the area from Neah Bay to points near the ocean.

Digging by Rigg several years prior to 1950 disclosed mainly mineral soil and very little peat. The area is mapped on the soil map of Clallam County (Smith et al., 1951) as tidal marsh, and part of it is shown as swampy land. The tidal marsh land type consists of fine estuarine sediments. The small amount of peat present contains so much salt that it would be useless for agriculture unless subjected to leaching for a number of years.

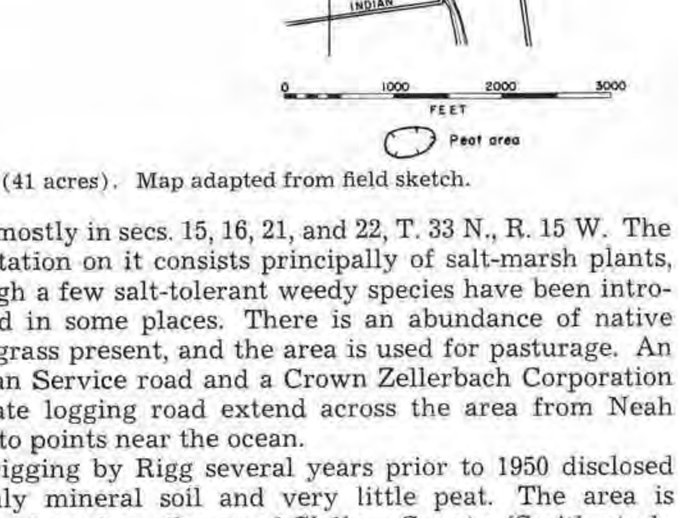


FIGURE 9.—Map and graphic log of hole in Sequim Game Reserve peat area (150 acres). Map adapted from U. S. Department of Agriculture soil map of western part of Puget Sound Basin.

Sequim Game Reserve peat area

The Sequim Game Reserve peat area (150 acres of peat and 80 acres of muck) is in secs. 4, 9, 16, and 17, T. 30 N., R. 3 W., in the eastern part of Clallam County. It is in the Sequim Game Reserve and is about 4 miles by road from the town of Dungeness. It borders Puget Sound and lies along a stream which flows into the Sound. The Soil Survey of Clallam County (Smith et al., 1951) maps it as Spalding peat, Rifle peat, and muck.

One hole (fig. 9) was bored near the west margin of the peat area in the NW¼ sec. 9. It shows 7 feet of dark-brown fibrous peat with which some wood peat is mixed in the lowest foot. Under this is 6 inches of dark-brown muck and then gray sand. The fibrous peat is raw at the top, disintegrated at the middle, and decomposed at the bottom. At the 2-foot level it is weakly acidic (pH 6.3).

Dungeness peat and muck area

An area of Spalding peat and adjacent area of muck are shown on the soil map (Smith et al., 1951) near Dungeness in secs. 5 and 6, T. 30 N., R. 3 W., and secs. 30 and 31, T. 31 N., R. 3 W. The Spalding peat extends a distance of approximately 1 mile just back of the coastal beach along the Strait of Juan de Fuca and at one point extends approximately ½ mile inland. The muck area adjoins the peat area on the south and extends irregularly southward about ½ mile. These areas of peat and muck were not investigated.

CLARK COUNTY DEPOSITS

Fargher Lake peat area

The Fargher Lake peat area (423 acres) is in secs. 23, 24, 25, and 26, T. 5 N., R. 2 E., about 8 miles north of the town of Battle Ground and about 6 miles south of Lake Merwin, which is an expansion of the Lewis River retained by a power dam. The river flows west into the Columbia River. The peat area is the old bed of Fargher Lake, which was drained many years ago by a ditch to a creek which flows southwest into the East Fork of the Lewis River. This ditch extends from the southwest corner of the peat through a break in the rather steep hills which surround the area. The area is shown as muck and peat on the soil map, Vancouver sheet (Mangum, 1913). It is shown on the La Center quadrangle (U. S. Corps of Engineers) as a treeless area with a swamp in it. The peat surface lies at about 620 feet above sea level, and the surrounding hills rise abruptly to 800 feet or more.

The origin of the depression formerly occupied by the lake and now only by the peat is not definitely known. This depression may owe its origin to Pleistocene glacial agencies, but more likely it is a result of volcanic activity. Volcanic rock is exposed at the north edge of the Fargher Lake depression, and the topographic form indicates a caldera. This interpretation is supported by the presence of a small volcanic crater occupied by Battle Ground Lake only 7 miles to the south.

Organic soil 1 foot deep is present at five of the holes of the profile (fig. 10). At hole 1 this soil contains a considerable amount of the siliceous remains of diatoms, and at hole 3 it is all diatomaceous. At deeper levels there is a large amount of greenish-gray lake mud in three separate layers, none of which extends entirely across the profile. The layers of peat between the layers of mud indicate the lapse of considerable time between the successive periods of maximum inwash of mud from the surrounding slopes; however, there was some inwash during much of the time, as is indicated by the layers of mixed sedimentary peat, lake mud, and clay. The layer of sedimentary peat shown at the north end of the profile indicates, though, that there was a considerable period of time during which little or no mud was washed in at that point. The upper portion of the inwash at hole 1 is greenish-gray clay.

The fibrous peat is brown, and most of it is disintegrated. The muck is mostly brown, and the organic soil is brown to black. The soil, which consists of a mixture of organic material and diatoms, is brown, and the diatomite at hole 1 is tan colored. The diatomaceous material in this peat consists of the siliceous remains of diatoms which grew in the water of the lake.

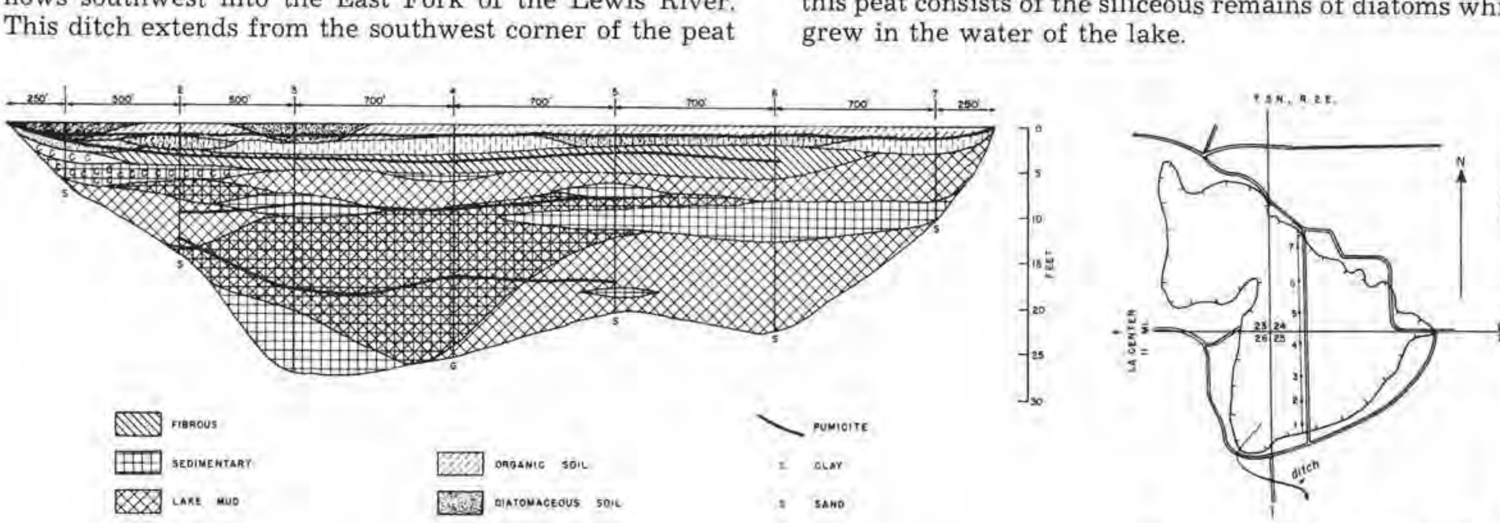


FIGURE 10.—Map and profile of Fargher Lake peat area (423 acres). Map adapted from U. S. Soil Conservation Service soil map.

Determinations made on material from holes 4 and 5 show that the peat is moderately acid at the surface and much less acid near the bottom, the change being gradual. In hole 4 the kind of peat or other material and the pH at the depth stated are as follows: At 4 feet, fibrous, 5.2; at 10 feet, mud and organic matter, 5.5; at 17 feet, mud and organic matter, 6.3. In hole 5 the data are: At surface, soil, 4.2; at 3 feet, fibrous, 4.5; at 15 feet, mud, 6.0; at 19 feet, mud, 6.3.

FIGURE 11.—General view of Fargher Lake peat deposit. Looking northeast from a neighboring hill. Photo by M. T. Huntting.

The presence of four layers of pumicite in this peat deposit is remarkable. That many pumicite layers have not been reported in any other peat deposit in the state. The pumicite is coarse (sand size), and the particles are rounded, not angular. It could be called fine pumice rather than pumicite. The upper layer is mostly brown, but it is tan colored in holes 2 and 7. In the second layer it is mostly tan, and in the deeper layers it is white or gray. Each layer of pumicite is fairly uniform in thickness, the upper being about three-fourths of an inch, and lower ones, about one-fourth of an inch. The upper layer is present at all holes. The second is not found at hole 7, and the third and fourth do not occur at holes 1, 6, and 7. The absence of some layers at the holes near the margins may be due to the mixing of the pumicite with the inwashed mud and clay so that distinct layers were not formed.

These facts indicate that the pumicite was deposited by falling from the air rather than being washed in from the surrounding slopes. The roundness of the particles of pumicite might suggest that it had been washed in, but rounded particles are common in air-borne ash. The darker color of the pumicite in the upper layer probably indicates oxidation of iron compounds which were components of the pumicite. The air-borne pumicite fell on the surface of the lake in four separate showers and sank to what was the bottom of the lake at the time of each shower. On the basis of the data now available, the sources from which these four layers of pumicite came cannot be determined with certainty. Probably some of it came from Oregon volcanoes, some from Mt. St. Helens, and possibly one layer came from the Battle Ground Lake crater.

Hansen (1947) bored a hole in this peat area for the collection of fossil pollen. He found 6 meters (approximately 20 feet) of sediments, with a layer of pumice at a depth of 1.1 meters (3 feet 7 inches). He says that this "was undoubtedly carried into the lake by streams heading in the mountains to the east." This view has been discussed above. The layer which Hansen found probably corresponds to the second layer of pumice or pumicite shown in the profile.

The crop of mint on this peat area was growing vigorously at the time it was inspected (July 1951). Persons who have been in the vicinity for many years stated that oats and other crops had been raised on this peat some years ago, but the change from these crops to mint is now practically complete. There is a small amount of waste land, too wet for utilization, near the west margin of the peat area.

Orchards peat area

The Orchards peat area (440 acres) in secs. 13, 14, and 15, T. 2 N., R. 2 E., and secs. 18 and 19, T. 2 N., R. 3 E., is about 3 miles long from east to west and less than ½ mile wide at its widest point. It is less than 5 miles north of the Columbia River, approximately 5 miles east of Vancouver, and a mile southeast of the village of Orchards.

The peat area (map, fig. 12) is very irregular in shape, and there are numerous ridges and islands of hard land in it. The depression in which it lies is evidently the result of water action in the Columbia River drainage during the evolution of the present channel of the river and the streams which flow into it from the north. Burntbridge Creek originates in the peat area and flows west. Lacamas Creek flows along the eastern border of the area. Both streams flow into the Columbia River.

The peat in this deposit (fig. 12) consists mostly of fibrous material with sedimentary peat under it in the deeper places. At all holes in the profile the peat rests on sand or gravel. The fibrous peat is brown; it is raw at the top and grades to decomposed at the bottom. The sedimentary peat grades from brown at the top through olive brown to olive green at the bottom. The layers of muck, wood peat, and peat slime are shown in the profile. The black organic soil at the surface was wet or very moist at the time it was investigated (July 1951). The fibrous peat at a depth of 2 feet in hole 2 is strongly acidic (pH 4.5).

A layer of brown pumicite 1 inch thick is present in all holes at a uniform depth of 1 foot. The fibers extending through the pumicite at hole 4 are straight and vertical, indicating that the sedges which formed the peat there were erect when the pumicite fell.

In 1951, mint was growing on the peat in the vicinity of the profile and there was one small patch of dill. Elsewhere in the peat area there were some other crops and a good deal of pasturage and waste land. There are some drainage ditches.

Dollar Corner peat area

The Dollar Corner peat area (196 acres) is nearly bisected by the north-south center lines of sec. 31, T. 4 N., R. 2 E., and sec. 6, T. 3 N., R. 2 E. It is just west of Dollar Corner, which is 3 miles west of Battle Ground and about 10

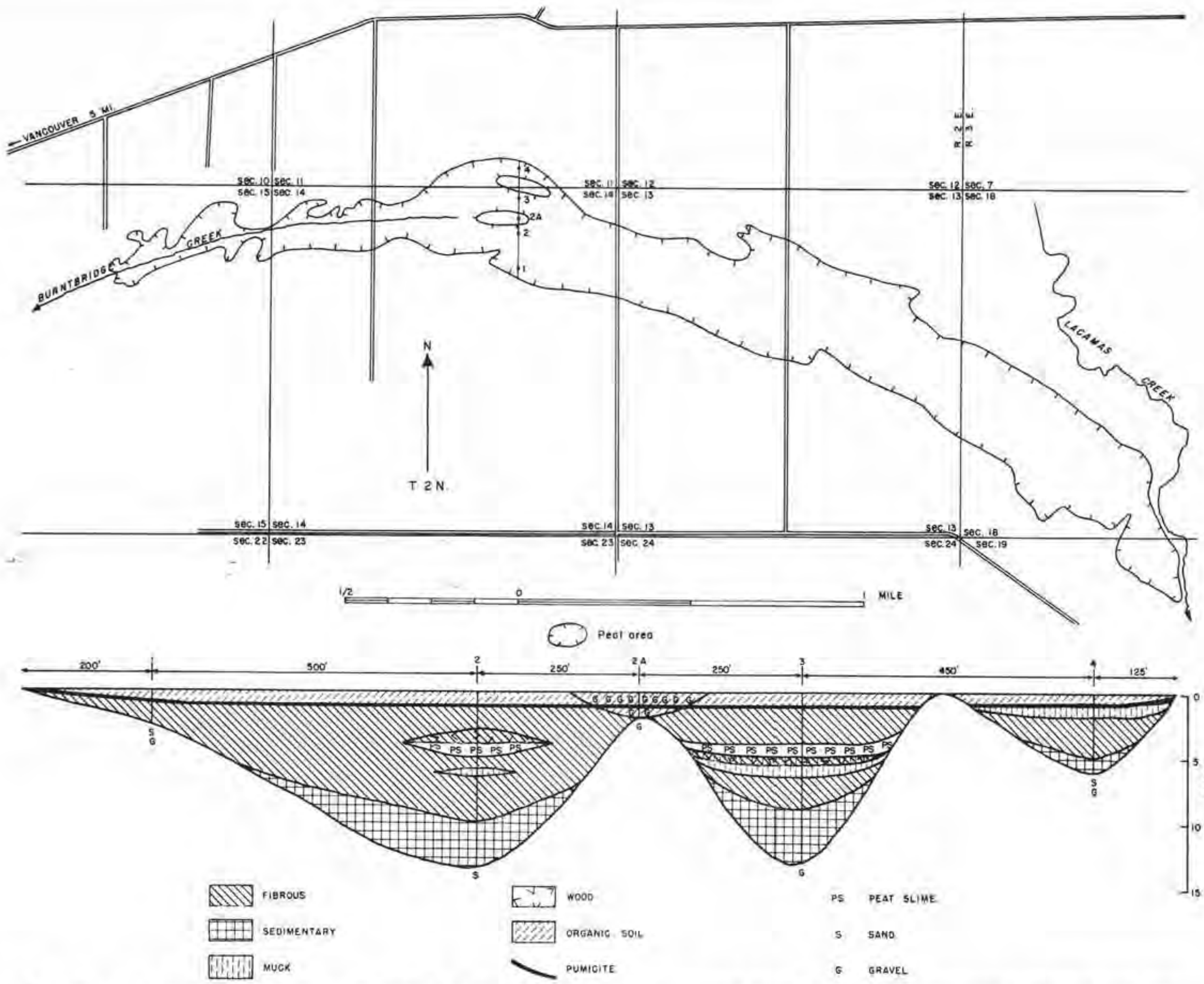


FIGURE 12.—Map and profile of Orchards peat area (440 acres). Map adapted from U. S. Soil Conservation Service soil map.

miles north of Vancouver. The area is about 1¾ miles long, north and south, and about 1,600 feet wide at its widest part. Mill Creek flows south through the entire length of the peat area and into Salmon Creek, which in turn flows into a tributary of the Columbia River.

One hole was bored in a weedy pasture on the west bank of the creek just south of the road which extends along the north line of sec. 6. The great abundance of siliceous remains of diatoms in the 5 feet of muck at the top of this hole indicates that there was standing water on the area in past times. Some physiographic change allowed the water to escape, and the creek cut its present shallow channel into the diatomaceous muck. The 3 feet of brown fibrous peat under this muck is disintegrated, and some of it is watery. The 1 foot of olive-gray sedimentary peat under the fibrous peat rests on 1 foot of tan-colored clay, under which is gravel.

No evidence was seen of attempts at agricultural utilization other than for pasturage. Not all of the area, however, was inspected.

Manor peat areas No. 1 and No. 2

The two Manor peat areas are in secs. 7 and 18, T. 3 N., R. 2 E. They are just west of the village of Manor, 4 miles southwest of Battle Ground, and about 7 miles northeast of Vancouver. Both are elongated north and south (map, fig. 15), and the road crosses both of them. The distance between them is about 700 feet.

Area No. 1 (1 acre) is mostly covered with a dense growth of hardhack. The brown fibrous peat (mostly decomposed) in the one hole (fig. 15) bored in this peat (300 feet south of the road) was probably derived from sedges. The hypnum peat is easily distinguished from the sedge peat by its texture. The sedimentary peat is brown to olive brown, and the 1-inch layer of pumicite in it is gray.

FIGURE 13.—Bean field in peat soil on C. Deffenbaugh farm, in Orchards peat area. U. S. Soil Conservation Service photo.

FIGURE 14.—Harvesting mint from a field on peat soil on C. Deffenbaugh farm in Orchards peat area. U. S. Soil Conservation Service photo.

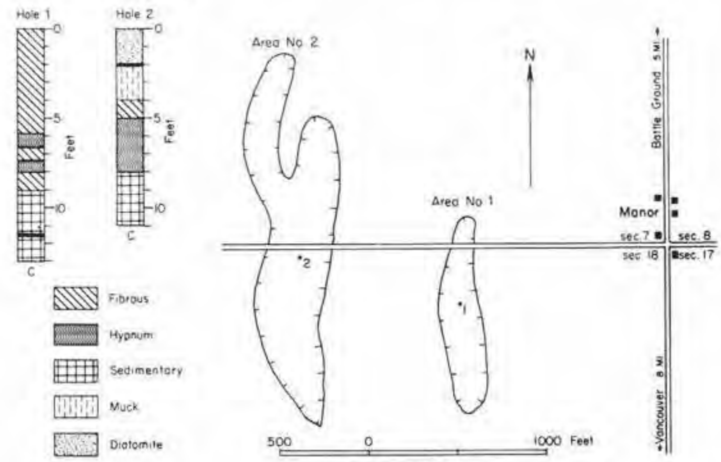


FIGURE 15.—Map and graphic logs of two holes in Manor peat areas (1 acre and 4 acres). Map adapted from U. S. Soil Conservation Service soil map.

Area No. 2 (4 acres) is mostly covered with sedges and reeds, but there is some grass, wild mint, and dock. The 2-foot layer of diatomite at the surface indicates that water stood on the area when this material was deposited. The diatomite is gray brown in color, and in July 1951 it was dry, except for some moisture in the lower 6 inches. The 1-inch layer of pumicite is brown. The fibrous peat is brown and disintegrated. The muck is dark brown. The hypnum peat is reddish in color; the upper portion of the layer is disintegrated, but the lower portion is rather raw. The sedimentary peat is olive brown, and the clay on which it rests is gray.

The relative position of the pumicite in these two peat deposits indicates that at the time of the ash-fall, peat formation in area No. 1 had only just begun, while in No. 2 it was complete. Evidently there was standing water on both depressions when the ash fell.

COWLITZ COUNTY DEPOSITS

Rockett peat areas

The two Rockett peat areas (total about 10 acres) are in the W½NE¼ sec. 10, T. 10 N., R. 1 W., on the farm owned and occupied by Robert Rockett on the Tower Road about 8 miles northeast of the town of Castle Rock. Both are on benches formed by the Toutle River, and both occupy former channels of the river. The lower one is about 20 feet higher than the present channel of the river. The upper peat area is about a quarter of a mile north of the lower one, and its elevation is about 20 feet higher than that of the lower one.

A bed of cream-colored pumicite 6 feet thick is exposed in the steep bank of a small steam issuing from a spring near the lower peat area. The exposure is only about 5 feet long, but the owner stated that there are other exposures at the same level. A few boulders of bog iron up to 8 inches in diameter occur on the surface of the soil just east of the lower peat area. They had been plowed up by the owner, and he found them to be so numerous that he had discontinued plowing at that place. They formed a layer about 10 inches thick over an area of probably less than 1 acre. Bog iron occurs at the surface at other places along the Toutle River.

Before farming operations modified these peat areas, water came into both of them from springs. Now the spring which formerly fed the lower one is utilized for the water supply of the farm, and the water from the upper spring has been diverted into a ditch. The lower area is now utilized for pasture and garden. The peat in it is 7 feet deep in the central portion and thins out to 1 foot near the margin. It is all fibrous, except for a small amount of sphagnum near the surface.

On a considerable portion of the upper area the peat consists of 4 feet of sphagnum. Some of this has been removed and sold, but in 1949 there was still a supply left. A part of this area contains fibrous peat, and oats were growing there in 1949. The peat in this upper area rests on fine sand which is mixed with finer pumicite.

Great changes have occurred in these peat areas during the 27 years prior to 1949. These changes are the result of clearing, drainage, and cultivation. The lower bog was inspected by Rigg in September 1922. Notes recorded at that time indicate that it was an extremely wet sphagnum bog with standing water a foot deep in some places. Living *Sphagnum* formed an almost continuous cover and grew into hummocks around small spruce trees and clumps of sedges. The list of plants made at that time includes most of the species of shrubs and herbs which are characteristic of sphagnum bogs in western Washington, and also a number of species of low shrubs and herbs which are characteristic of swamps. These two records made 27 years apart indicate how completely bog plants and bog conditions can be destroyed by man's activities, with the result that an area which under natural conditions was useless from the economic standpoint now contributes to human welfare.

Silver Lake peat areas

The Silver Lake peat areas as mapped by the U. S. Soil Conservation Service (fig. 16) comprise 612 acres at the west end of Silver Lake, in secs. 4, 5, 8, and 9, T. 9 N., R. 1 W., and 56 acres in each of the two areas at the northeast end of the lake, in secs. 25 and 26, T. 10 N., R. 1 W. Older mapping (Mangum, 1913) shows a peat and muck area in secs. 4, 5, 8, 9, 10, 15, and 16, T. 9 N., R. 1 W. This

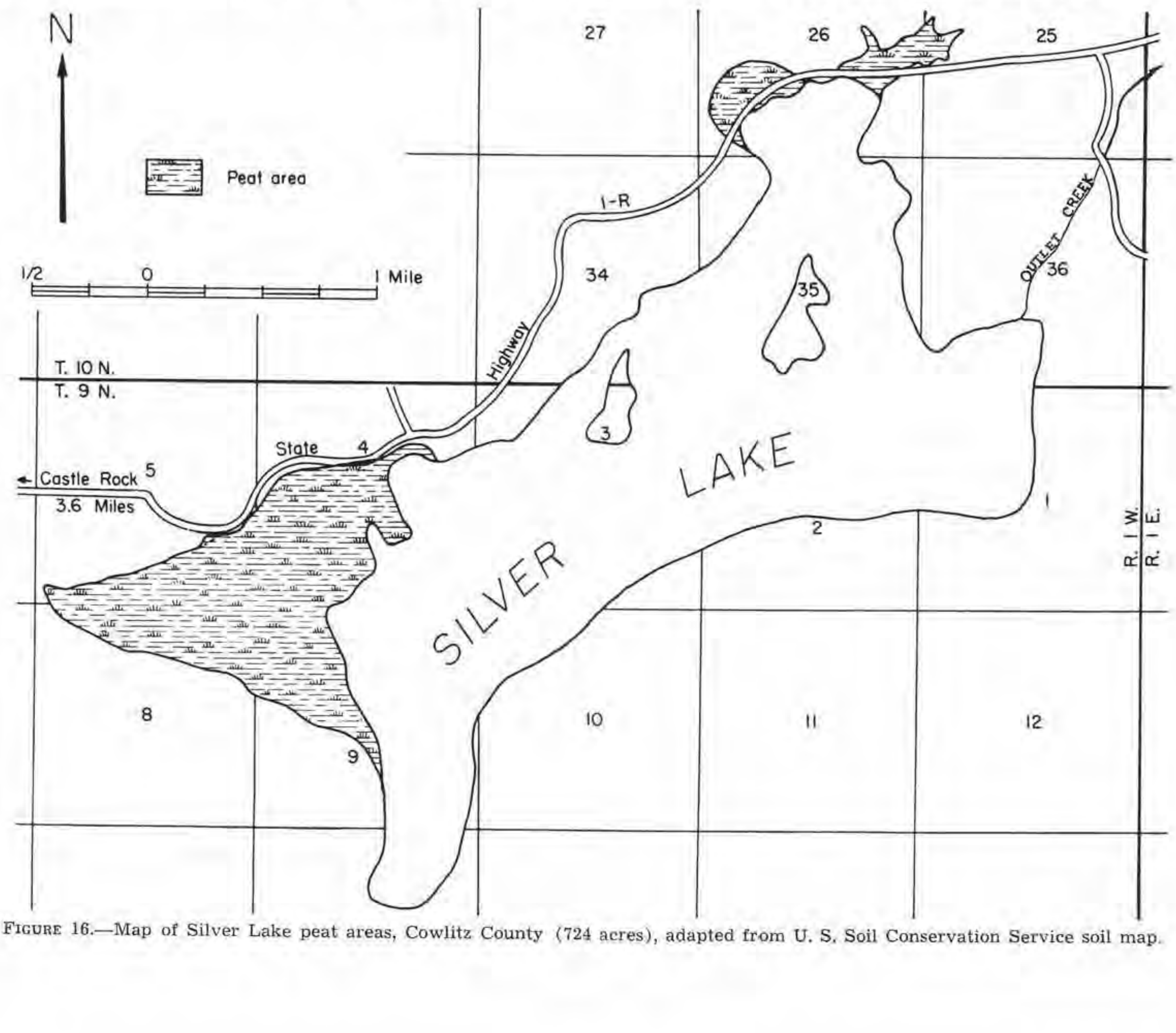


FIGURE 16.—Map of Silver Lake peat areas, Cowlitz County (724 acres), adapted from U. S. Soil Conservation Service soil map.

area borders the west and south shores of Silver Lake and also extends a short distance along the east shore. The same map also shows a narrow strip of peat and muck (estimated at 180 acres), not continuous with the one just mentioned, extending along the northeast, north, and east shores. A marsh corresponding generally in location and area to the larger area on the Mangum map is shown on the Olequa quadrangle. An island rises about 40 feet above this marsh near the lake. A branched drainage ditch with a total length of almost a mile is shown extending eastward through the marsh to the west shore of the lake, and several streams flow to the ditch from the steep hills which border the south side of the marsh. Streams also flow into the lake through ditches across the marsh at the south end of the lake, and several other streams enter the lake from the southeast. Outlet Creek flows from the lake to the Toutle River. It leaves the lake at its easternmost tip just north of where the longest inlet (Hemlock Creek) flows into the lake.

The depression occupied by Silver Lake and the adjoining peat appears to owe its origin to the damming of a broad but short tributary valley at its mouth by extensive and thick fluvial deposits from the Toutle River. The tributary drainage did not carry sufficient load to fill its own valley at a rate fast enough to keep up with deposition in Toutle Valley. Aggradation of the Toutle River probably was contemporaneous with aggradation of the lower Columbia River and its tributaries, which resulted from a rise in base level accompanying a rising sea level, probably in Pliocene time (Lowry and Baldwin, 1952, p. 7).

Subsequent lowering of base level allowed the Toutle to cut a youthful valley in its own earlier deposits, but the tributary, which drained Silver Lake, had small erosive power and was unable to keep pace in its cutting, thus allowing the lake to persist.

It is possible also that blocking of the Toutle River channel by lava flows exposed on both sides of the river in secs. 15, 16, 17, 20, and 21, T. 10 N., R. 1 W., may have been a factor, possibly the determining one, in the origin of Silver Lake.

Changes in the level of Silver Lake may have occurred since the formation of the depression in which it lies. Its outlet (Outlet Creek) is small. Whether this channel has ever been blocked by landslide material or some other obstruction has not been investigated.

Pumicite is known in a number of places in the Silver Lake area. As noted under the description of the Rockett peat areas, there is a 5-foot bed of pumicite in the bluff rising from the west border of the lower Rockett bog in the NE¼ sec. 10, T. 10 N., R. 1 W., and pumicite is mixed with the sand on which the peat in the nearby upper bog rests. Evidence of volcanic ash (pumicite) in the region was found by Hansen (1947). He found ash underlying 3 meters (approximately 9 feet 10 inches) of the peat which borders Silver Lake. It should be remembered, however, that Rigg (see below) found sand, gravel, and blue clay under the peat in the same general area.

The road from Castle Rock to Spirit Lake passes close to the main west peat area about 5 miles from Castle Rock. In August 1949 the land between the road and the peat area on the west shore of Silver Lake was so overgrown with trees and brush that the peat area could not be seen from the road. The road also passes close to the extreme northern tip of the lake. There was a dense growth of vegetation in the shallow margin of the lake there, but no continuous mat was seen. Considering the form of the lake and the course of the road as shown on the Olequa quadrangle, it seems probable that the area mapped as muck and peat on the Vancouver sheet of the soil survey (Mangum, 1913) was not seen in the 1949 investigation.

Hansen (1947) speaks of Silver Lake as "a shallow lake." He bored the peat to obtain fossil pollen for the study of forest succession in the region, and found 3 meters (approximately 9 feet 10 inches) of peat underlain by volcanic glass (pumicite). From a study of the pollen he found that the forest succession in the region was similar to that recorded above the pumicite in Puget Sound bogs. This seems to indicate that considerably less time has elapsed since the formation of peat began here than has elapsed since peat formation began in the oldest of the bogs of the Puget Sound region. It is possible, of course, that there may be peat under the pumicite that Hansen found in this peat. If this should be present, the lake may be considerably older than would be indicated if the ash lies on the bottom of the lake. Often during the boring of peat deposits in various parts of the state, deposits of pumicite have been found that were so compact that it was impossible to penetrate them with either the New American peat borer or the Hiller borer.

The main peat area bordering the west shore of the lake was investigated by Rigg in September 1922, and some borings were made. The following information is based on field notes recorded at that time.

A mat of vegetation extending out from the mucky shore onto the lake was reached by walking about a quarter of a mile from the stage road over an old road and a trail. The mat was very wet, and local information indicated that it rose and fell with changes in the lake level. The mat was about 1 foot thick and was composed of roots and rootstocks of herbaceous swamp plants together with some roots of willow and sweet gale. There were 10 to 11 feet of water and peat slime under the mat. The bottom was coarse sand, fine gravel, and blue clay. The area of the mat seen at that time was estimated to be 40 or 50 acres. The tangle of woody and herbaceous vegetation on the portion of the mat that was nearest to the shore was continuous from the mat to the mucky shore. There were some channels of open water in the mat, and a boat was used in part of the investigation. In some places an oar was thrust down into soft material at the bottom (to a depth of about 8 feet), but nothing hard was encountered.

One area (10 or 15 acres) on the mat was a sphagnum bog. It had the usual bog herbs and shrubs, and wild cranberry vines were numerous. Some swamp species grew with the bog species. *Sphagnum* grew among the bog and swamp plants, but did not form a complete cover. This bog was in a very early stage of development. Old notes recorded by Rigg during World War I, when *Sphagnum* moss was being used by the Red Cross for the preparation of surgical dressings, indicate that a local resident reported considerable areas of living *Sphagnum* around Silver Lake at that time.

Stankey Farm peat area

The Stankey Farm peat area (about 2 acres) was inspected by Rigg September 10, 1922. It is a sphagnum bog on Gus Stankey's farm, 1½ miles north of Silver Lake Post Office, probably in the SW¼ sec. 28, T. 10 N., R. 1 W. The bog is situated on a flat undrained area in a region of low hills. It is in a little valley but not at the bottom of the valley. Water, 1 foot deep in some places, was standing on the bog, though the summer had been very dry and there had been very little rain in September. In addition to the main area there were patches of bog varying from 3 to 15 feet in diameter extending for an eighth of a mile to the southeast. An abundance of bog and swamp plants, including wild cranberry vines which bore excellent fruit, were growing on the bog. *Sphagnum* was growing vigorously and formed hummocks over logs and around trees and shrubs. Western red cedar trees 2 to 10 feet tall were abundant. There were also a few Douglas fir and red alder trees of about the same size as the cedars. The shrubs on the neighboring hillside were those that are characteristic of dry gravelly soil.

The peat was 1 to 2 feet deep in all places that were tested. It rested on blue clay that in some places was mixed with organic matter.

FERRY COUNTY DEPOSITS

Sanpoil River peat area

The Sanpoil River peat area is a mucky area which contains only a small amount of peat. It is at the center of the N½NW¼ sec. 4, T. 36 N., R. 33 E., about 1 mile by road east of Republic. The Sanpoil River, which flows south to the Columbia River, crosses the area. The data at hand are not sufficient for even an estimate of the extent of the peat, but it might be of the order of 20 acres.

One hole was bored to a depth of 7 feet. The muck occupying the upper 2½ feet of this hole is black. Underlying the muck is an 18-inch layer of diatomite, a 2-foot layer of white marl, and a 1-foot layer of mixed marl and sedimentary peat, all indicating that there was standing water on this area at the time of the deposition of these materials. The deposit rests on dark-gray sand. No pumicite was found in this peat.

Curlew Lake peat area

The Curlew Lake peat area (about 6 acres) is at the center of sec. 17, T. 37 N., R. 33 E., about 7 miles north of Republic. Its elevation is 2,347 feet above sea level. It is reached by a rough road (about ½ mile long) that extends east of Curlew Lake from the main road. The peat is in an embayment of the lake and extends from the open water of the lake to the rocky shore. Sedges and cattails grow on the peat.

The total depth of the one hole bored in this area is 14½ feet. The fibrous peat occupying the upper 4 feet is dark brown, and the lower 1 foot is disintegrated. A determination made on the upper foot of this peat shows that it is slightly alkaline (pH 7.7); this is one of the very few alkaline peat areas in the state. Near the margin of the peat the water of the lake is slightly acid (pH 6.5). The 2 feet of sedimentary peat under the fibrous peat is olive green in color. The 8½-foot layer of marl under the sedimentary peat is white at the top, and from about the middle to the bottom it is tan colored. The marl rests on blue clay. No pumicite was found in this peat.

Copper Lakes peat area

The Copper Lakes peat area (about 5 acres) is in secs. 9, 10, 15, and 16, T. 36 N., R. 32 E., about 5 miles by road southwest of Republic. It lies along the stream which flows out of Copper Lakes to Granite Creek, a tributary of the Sanpoil River. The vegetation on the peat is a combination of swamp plants and small peat-bog birch trees.

One hole was bored about 20 feet north of the north lake at the west side of the outlet stream. The mixture of fibrous peat and wood peat, which forms the upper 1 foot of this deposit, is dark brown and, like the surface layer of the Curlew Lake peat, is slightly alkaline (pH 7.7). The water of the lake is neutral (pH 7.0). The second foot of the deposit is dark-brown fibrous peat. Under this is 1 foot of cream-colored marl, and under the marl is 6 inches of mixed marl and sedimentary peat, brown in color. Next is 1 foot of cream-colored marl, and from there to the bottom is tan-colored marl. The pH of the marl at the 5-foot depth is 6.5. There is a 2-inch layer of light-gray pumicite just above the 6-foot depth. At the bottom of the deposit (11 feet) is 1 foot of blue clay underlain by sand.

GRANT COUNTY DEPOSITS

Crab Lake peat area

The Crab Lake peat area (1,415 acres) is in secs. 7, 8, 9, 10, 11, 17, and 18, T. 22 N., R. 30 E., and secs. 12 and 13, T. 22 N., R. 29 E. It is mapped as muck and peat by the Soil Survey (Strahorn et al., 1929). Its western end is only a few hundred yards south of the town of Wilson Creek, which is about 40 miles south of Grand Coulee Dam. State Highway 7 extends close along the south side of the area and leads to Spokane, about 90 miles to the east. The Great Northern Railway extends along the north side of the area and crosses it near the eastern end, which is about 2 miles west of the town of Marlin. A county road from Wilson Creek crosses the area from north to south near the western end.

The present surface of the peat (1,270 feet above sea level) is the old bottom of Crab Lake, which was drained by a ditch about 1907. Crab Creek flows west in this ditch through the entire length of the peat area, and the drainage eventually reaches Moses Lake. The peat lies in a deepened part of the scabland channel through which Crab Creek flows. Hansen (1941) says, "The lake [Crab Lake] was impounded by Wilson Creek sediments where it empties from the north into Crab Creek." The peat area is mostly bordered by scabland, but Ephrata sandy loam and Washtucna very fine sandy loam form some parts of its boundary (Strahorn et al., 1929). The scabland is basalt, and there are steep basalt cliffs not far back from the peat.

Bretz (1923) investigated the scablands of the Columbia Plateau. He says, "The terms 'scabland' and 'scabrock' are used in the Pacific Northwest to describe areas where denudation has removed or prevented the accumulation of a mantle of soil and the underlying rock is exposed or covered largely with its own coarse angular debris." He also says that the prevailing feature of scabland topography is indicated by the term which he uses, "channeled scablands." "They are scored by thousands of channels eroded in the underlying rock." The wheat lands of the region are on loessal soils of the plateau at a somewhat higher elevation than the scablands. Both the scablands and the loessal soils near the peat are largely treeless.

Hansen (1941) described the botanical features of the region and reviewed the papers dealing with the geological features. He collected fossil pollen from borings he made in the peat. From a study of this pollen he found that "grassland has been predominant during most of the time recorded by the sediments."

The locations of the seven holes that were bored in this peat in 1949 are shown on the map (fig. 17). The sequence and thickness of the various layers of material (peat,

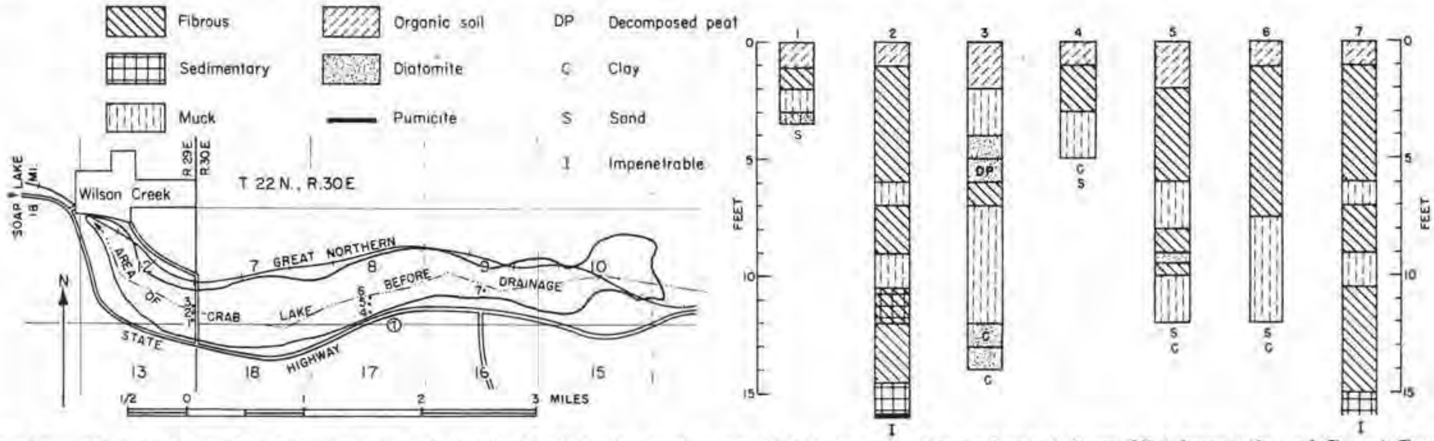


FIGURE 17.—Map and graphic logs of seven holes in Crab Lake peat area (1,415 acres). Map adapted from Metskers atlas of Grant County.

muck, and diatomite) vary greatly, and for this reason the holes are shown separately (fig. 17). Though holes 1, 2, and 3 are in line, it is difficult to correlate the layers of materials in them into a consistent profile. This could be done only by boring holes very close together, and the limitations of time did not permit this. The same is true of holes 4, 5, and 6. Hole 6 is on the south bank of the ditch (Crab Creek), which is about 30 feet wide at this point. No borings on this line were made north of the creek. Bottom was not reached in the two deepest holes (2 and 7), because the material encountered was too compact to permit boring farther. In hole 2 the impenetrable material is white pumicite, and there may or may not be more peat under it. It will be noted that of the seven holes this is the only one in which pumicite was found. The mineral material at the bottom of all holes where bottom was reached is clay or sand or both.

As is shown in figure 17, more than half of the material encountered in the borings is fibrous peat. It is mostly brown, but some of it is light brown, and one sample is black. It is mostly neutral (pH 7.0), but one sample at the 2-foot depth is acid (pH 4.5). There is a considerable amount of muck; the layers of it occur at various levels; and there are two layers in three of the holes. The pH of one sample of black muck was 6.5. Diatomite, mostly light brown, is found in three holes, and there are two layers in one of these. The pumicite is light gray. The water in the ditch is neutral (pH 7.0).

Hansen (1941 and 1947) found 6.75 meters (approximately 22 feet) of sediments in the Crab Lake deposit, with pumicite at 5 meters (approximately 16 feet 5 inches). The depth which he found is considerably greater than the maximum depth found in 1950, but he may not have bored near any of the 1950 holes, and it should be remembered that bottom was not reached in the deepest holes bored in 1949 and 1950.

Much of the peat area was in oats in 1949 and 1950. There was one wheatfield north of the ditch. Strahorn (1929) says, "Muck is very productive when drained and placed under cultivation, but peat generally requires the addition of mineral fertilizer for successful crop production. The largest area of muck and peat occurs at Wilsoncreek and west of Marlin and is entirely under cultivation. Wheat and oats yield exceptionally well, wheat averaging about 50 bushels an acre and oats about 75 bushels, but yields of as much as 120 bushels of oats have been reported. Timothy and alsike clover produce 2½ to 5 tons an acre. Where not cultivated the land affords excellent pasture."

Rocky Ford Creek muck and peat area

The long narrow strip (440 acres) mapped as muck and peat on the soil map (Strahorn et al., 1929) extends along Rocky Ford Creek for a distance of 4 miles in secs. 20, 21, 28, 32, and 33, T. 21 N., R. 27 E., and secs. 4, 5, and 8, T. 20 N., R. 27 E. It is about a quarter of a mile wide at its widest point. It is mostly muck with a layer of diatomite in some places. The amount of peat is practically negligible. The creek originates in a spring in sec. 9, T. 21 N., R. 27 E., and flows to Moses Lake. In 1950 there was a fish hatchery on the creek in sec. 16. The soil bordering the area is mostly Ephrata sandy loam, but at the east border there is some scabland and at the north and at the south end it is bordered by Naylor and Red Rock soils, undifferentiated.

In 1950 there was standing water in many places on this area and the vegetation of the area was composed mostly of cattails, tules, and other aquatic plants. In a few places which were not quite so wet there were thistles and other weeds.

Eight holes bored in the area show very little peat. Apparently the area is underlain mostly by muck. Fibrous peat was found in only three holes, all in the NE¼NE¼ sec. 5, T. 20 N., R. 27 E. Of these three holes, one shows 3 feet of fibrous peat overlain by 1 foot of muck and underlain by 4 feet of muck and 2 feet of diatomite lying on sand; another shows 1 foot of fibrous peat underlain by 6 inches of muck, under which is clay and sand; and the other shows 1 foot of mixed fibrous peat, wood peat, and sand, underlain by gravel, and overlain by 2 feet of muck. A fourth hole in this same vicinity shows 3 feet of muck which includes 2 thin layers of diatomite and rests on sand and gravel. Three holes bored in the SW¼SW¼ sec. 28, T. 21 N., R. 27 E., show from 3 to 6 feet of muck resting on sand and gravel. The deepest hole shows 6 inches of diatomite at a depth of from 1½ to 2 feet. One hole in the NW¼NW¼ of the same section shows 3 feet of muck resting on sand.

The muck is dark brown to black. It is neutral (pH 7.0) and has a strong odor of hydrogen sulphide. The small amount of fibrous peat is dark brown and decomposed. The diatomite is tan to brown in color.

The area is utilized as a part of the stock range of the region, but no evidence of attempts at any other utilization was seen.

GRAYS HARBOR COUNTY DEPOSITS

North Bay peat areas No. 1, No. 2, and No. 3

The three North Bay peat areas, all of which have one or more commercial cranberry bogs, are numbered 1, 2, and 3 on the map (fig. 18). They lie close to the north shore of North Bay, which is the northern portion of Grays Harbor. The harbor is broad, but it narrows at its eastern end where it receives the Chehalis River. It is partially cut off from the Pacific Ocean by sand-dune-covered peninsulas, which extend from the north and the south. The three peat areas are about 15 miles northwest by State Highway 9C from Hoquiam.

Area No. 1 (160 acres) is in sec. 13, T. 18 N., R. 12 W. The North Bay Cranberry Company has 13 acres of commercial cranberries in this area, and they have more land cleared, some being ready for planting. Much of the uncleared area is timbered and has brushy undergrowth. In some places, however, the vegetation consists of shrubs and herbs which are characteristic of sphagnum bogs, and living *Sphagnum* is common.

This area was investigated by boring two holes (fig. 18) and making a number of observations on the banks of drainage ditches. All these indicate that the peat is relatively shallow. The mixture of sphagnum and fibrous peat at the surface is raw, but the fibrous peat under this grades into a decomposed peat at the bottom. The clay on which it rests is blue. The peat is rather strongly acidic (pH 3.5 to 4.5).

Area No. 2 (322 acres) is in secs. 17 and 18, T. 18 N., R. 11 W., and sec. 13, T. 18 N., R. 12 W. The investigations here were made in and near Cleaver's North Bay commercial cranberry bog (2½ acres). The maximum depth of peat found is 6 feet (fig. 18). There is 1 foot or less of sphagnum peat at the surface, and under this is fibrous brown peat which is mucky toward the bottom. It rests mostly on greenish-gray clay, but there is some sand.

In the brushy area near this bog, sweet gale is the common shrub and perennial *Sanguisorba* is the common herb. Both of these are found in sphagnum bogs near the Pacific Coast, and here some living *Sphagnum* is on the ground among them.

In area No. 3 (119 acres), which is in secs. 17 and 18, T. 18 N., R. 11 W., are six commercial bogs of 5 acres each or less, and preparations for extending commercial production are under way. Most of the peat (fig. 18) is fibrous and is brown to black in color. Sphagnum, where present, forms only a thin layer at the surface. There is some woody peat and also some peat slime. In some places there is muck at the bottom. All the peat rests on clay.

New areas for commercial cranberry bogs are being cleared of trees and brush, and new plantings are being made in all three of these areas. Conditions for rapid in-

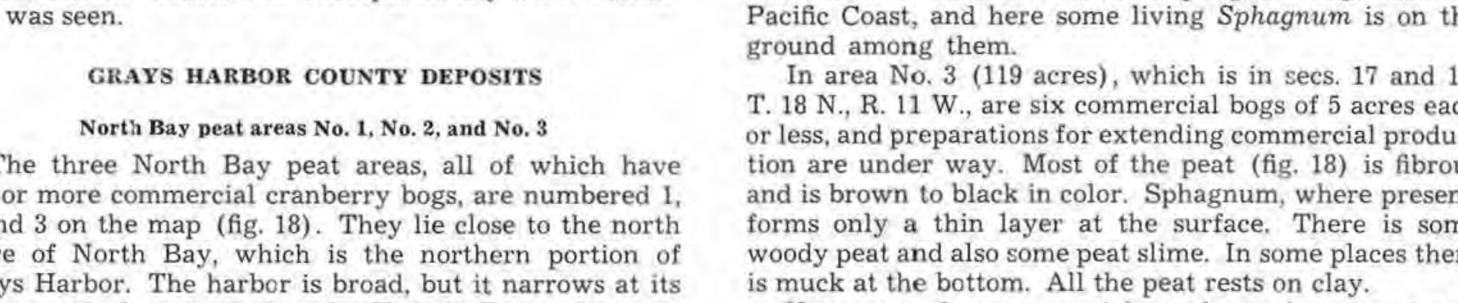


FIGURE 18.—Map and graphic logs of nine holes in North Bay peat areas (160 acres, 322 acres, and 119 acres). Map adapted from U. S. Army Map Service photomosaic.

crease in cranberry production seem favorable in these areas.

Ocean Dune peat area

The Ocean Dune peat area (115 acres) is in the E½ SE¼ sec. 22 and W½SW¼ sec. 23, T. 18 N., R. 12 W., on the mile-wide strip of sand between North Bay and the Pacific Ocean. This strip, which is about 6 miles long, is all mapped (Mangum, 1912) as Westport fine sand except at the extreme south end, where it is shown as coastal beach. The sand is characterized by Mangum as "brown fine sand several feet in depth of so loose and incoherent a nature that it is easily moved by the wind unless protected by vegetation." It is stated to be "of marine and eolian origin, having been thrown up by the waves and then drifted into dunes by the wind." The Moclips quadrangle shows this peat area as marsh. Most of it is covered with a dense growth of shrubs in which sweet gale and hardhack are the dominant plants. Adjacent to the peat, where there is no cover of vegetation, are small active dunes.

One hole bored in a dense growth of sweet gale shows nothing but the living roots of this shrub in the upper 1 foot. Below this is 1 foot of peat slime and then 5 feet of brown fibrous peat mixed with woody peat. Under this is 1 foot of muck and then sand.

Utilization of this peat is improbable. It is too near sea level to permit adequate drainage. If the sandy soil near the peat were cleared of shrubs, moving dunes would probably cover the peat area.

Ocean City peat and muck area

The Ocean City area of peat and muck (estimated at 10 acres) is in the SW¼SE¼ sec. 34, T. 19 N., R. 12 W., about 1 mile north of Ocean City, 2 miles south of Copalis, and about 1 mile east of the line of coastal dunes. It lies in a depression in silty clay loam at an elevation of 60 feet above sea level. There is a commercial cranberry bog of 7½ acres on it. In some places there is 3 feet of fibrous peat, under some of which is a foot of mud and then silty clay. In other places there is 2 feet of muck over the clay, and there is no peat.

This is the site of the old Chabot commercial cranberry bog, which was established about 1896. It is believed this was the first commercial cranberry bog in the state of Washington. It was visited by Rigg in 1921. At that time Mr. Chabot had 2½ acres in cranberry production, and another 2 acres had burned and gone back to its wild state. The flora of the wild area was composed of bog herbs and shrubs, including native cranberry vines. There were patches of living *Sphagnum* but no continuous cover of it. Mr. Chabot continued the commercial production of cranberries here for many years, but the bog was eventually abandoned. The commercial bog was put into production later by George Cleaver.

Pleistocene peat buried under clay is revealed in an excavation in the Ocean City peat area. This peat or peatlike material is black and solid but can be broken easily with the hands. No plant remains are visible in it to the unaided eye. This peat approaches lignite in composition. The banks of the excavation show 3 feet of ordinary fibrous peat at the surface, underlain by 7 feet of greenish to bluish clay, under which is 2½ feet of lignitic peat resting on clay. There is no positive indication as to when this peat or peatlike material was laid down. It may be interglacial in age. Layers of peat covered with thick deposits of sediments are common in western Washington (Hansen, 1938, and Hansen and Mackin, 1940), but they are in glaciated regions, whereas the Ocean City deposit is in a region which is not known to have been glaciated. Further investigation of this material is desirable.

Carlisle Lakes peat area

The Carlisle Lakes peat area (415 acres) is in secs. 4, 8, 9, 17, and 18, T. 19 N., R. 11 W. (map, fig. 19). It is reached by an unimproved road and a trail from Whalen's farmhouse, which is about 1 mile south of the Carlisle School on State Highway 9C. The airline distance from the west side of the peat to the Pacific Ocean is 4½ miles. The four lakes in the peat area and also a small marsh near them are shown on the Moclips quadrangle. The lakes and the peat surrounding them lie in a shallow depression in silty clay loam in a relatively flat region about 60 feet above sea level. Damon Creek flows eastward through peat land from the largest of these lakes to the Humptulips River, which flows into Grays Harbor. Cedar Creek originates in the southwest part of the peat area and descends about 60 feet in its westward course to the Copalis River, which flows into the Pacific Ocean.

The peat area is partly sphagnum bog, partly sedge meadow, and partly swamp on which there is standing water as much as 1 foot deep in some places. On the sphagnum bog there are the usual herbaceous and shrubby species, including an abundance of the small creeping woody vines of the native cranberry. Living *Sphagnum* moss covers considerable areas, and there is some living *Hypnum* moss. Swamp vegetation flourishes in the wetter places. At the margin of the lakes the surface of the bog is comparatively firm and does not sink perceptibly under the weight of three men. There are no mats of vegetation on the lakes. Much of the peat is covered with a growth of lodgepole pine trees, among which are some small western red cedar trees and some small cascara trees. Some of the pines are only 2 or 3 feet tall, but others reach a height of 40 feet.

The seven holes bored in this peat reveal sphagnum peat, fibrous peat, and muck (fig. 19). The sphagnum peat is brown and raw, and the quantity is being increased by the growth of *Sphagnum* at the surface. Much of the fibrous peat is disintegrated, and some is decomposed. Most of it is wet, and some is watery. The clay under the peat varies from gray to blue gray and greenish gray, some being firm and some, soft. Acidity tests were made on material from hole 7, which is at the margin of the largest lake. The black forest debris at the surface and the sphagnum peat at the 2-foot depth are strongly acidic (pH 3.7). The clay at the 7-foot depth is weakly acidic (pH 5.3).

No evidence of any attempts at utilization of this peat was seen, though *Sphagnum* moss for the preparation of surgical dressings by the Red Cross was obtained here during World War I. The sphagnum is of good quality,

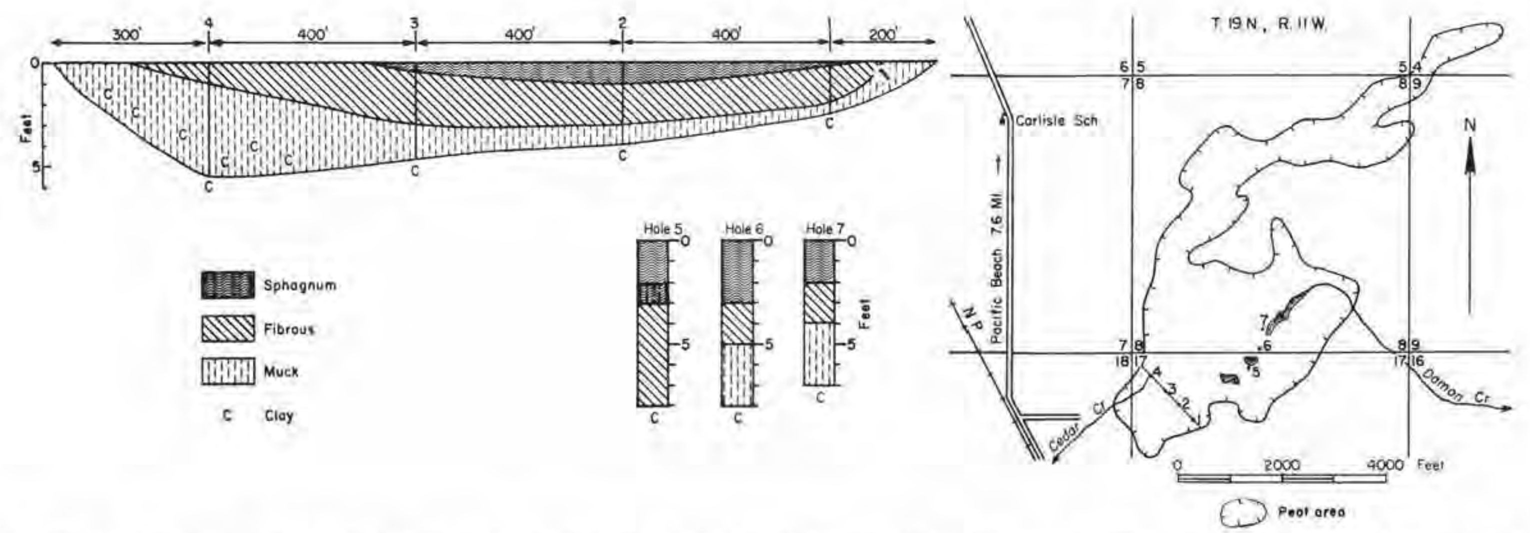


FIGURE 19.—Map, profile, and graphic logs of three holes in Carlisle Lakes peat area (415 acres). Map adapted from U. S. Army Map Service photomosaic.

but the quantity is too limited to justify its removal for commercial purposes. It could be used locally for litter in chicken houses or as a soil amendment on gardens.

MacAfee muck and peat area

The MacAfee muck and peat area (200 acres estimated) is in secs. 19, 20, and 30, T. 21 N., R. 10 W., about 8 miles by road west of U. S. Highway 101 (map, fig. 20). In a direct line it is about 5 miles northwest of Humptulips. No soil survey has been made of the region. The peat area lies within the Quinault Lake quadrangle. The timber on the land around the area has been logged.

The southern portion of the area is a wet meadowlike swamp with 1 to 2 feet of muck mixed with some fibrous peat. The underlying clay is gray green to yellow. The northern and northeastern parts of the area are boggy. A profile (fig. 20) shows living *Sphagnum* and shallow decomposed sphagnum peat, watery decomposed fibrous

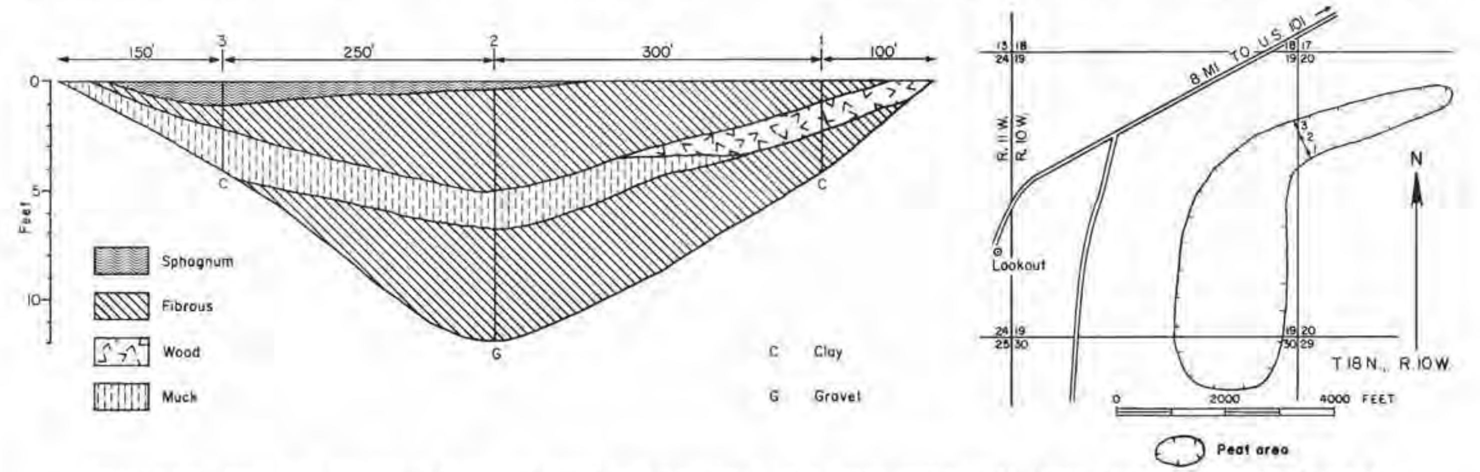


FIGURE 20.—Map and profile of MacAfee muck and peat area (200 acres, estimated). Map adapted from field sketch.

peat, brown wood peat, and dark-brown to black muck. Under this is greenish-gray clay, sand, and gravel. No evidence of any attempts to utilize the area was seen.

Grayland peat area

A part of the Grayland peat area is in Grays Harbor County near the Pacific Ocean, south of Grays Harbor, but most of it is in Pacific County and is described under Pacific County.

Prairies

Several prairies within a few miles of the Pacific Ocean have shallow muck, but no peat was found in them. Some patches of living *Sphagnum* moss occur and also some shrubs which are characteristic of sphagnum bogs. There is a scattered growth of lodgepole pine trees and also some very small hemlocks and a few crab apple and cascara trees. These prairies are wet, and the water table is mostly about 1 foot from the surface in summer. They are thus quite different from the dry gravelly prairies in Pierce, Mason, and Thurston Counties.

Baker's Prairie (about 300 acres) is in the Quinault Indian Reservation about 4 miles northeast of Moclips. On the Raft River quadrangle it is shown as lying in secs. 22, 23, 26, 27, 34, and 35, T. 21 N., R. 12 W. However, the prairie covers much less area than is indicated on the map and is only 0.4 mile wide where crossed by a road maintained by the Aloha Logging Company.

Holes dug with a shovel at a number of places in the prairie revealed 1 to 2 feet of black muck, under which was gray clay. Water accumulated in the holes as they were being dug. There was no standing water on the surface at the time of the investigation (August 1949), but local reports indicate that about a foot of water stands on it in winter. The climate of the region is cloudy and foggy, and the annual precipitation is reported locally to be 80 to 90 inches. Nearby, at Quinault, the annual precipitation is 128 inches, and at Clearwater, in Jefferson County, it is 123 inches. Several other prairies and also some swamps and sloughs are reported to be in the vicinity, but none of these were examined for peat.

No cranberries were seen growing in the region, but local reports indicate that there are some in the vicinity of Baker's Prairie, and that a commercial cranberry bog (Warwick bog) was established there some years ago and that it still produces good berries, though no commercial use is made of them.

Carlisle Prairie (150 acres) is about a mile north of the Carlisle Lakes peat area. It is in secs. 5, 6, 7, and 8, T. 19 N., R. 11 W., and is similar to Baker's Prairie.

Swamp forest

An extensive swamp forest covering parts of 10 sections in T. 21 N., R. 11 W., contains a large quantity of muck and some peat (about 50 acres of peat). It is in the Quinault Indian Reservation and begins a few miles east of Baker's Prairie. It is shown as swamp on the Raft River quadrangle. A surface growth of *Sphagnum* is common in this forest, and there are some sphagnum bogs. In the largest one examined (about 20 acres) are 1 foot of sphagnum peat and 3 feet of fibrous peat which rest on gray clay. The forest has been much modified by logging and the building of logging roads, but the growth of *Sphagnum* has continued.

ISLAND COUNTY DEPOSITS

Cranberry Lake peat area

The Cranberry Lake peat area (180 acres) is in secs. 34 and 35, T. 34 N., R. 1 E., and secs. 3 and 10, T. 33 N., R. 1 E., near the north end of Whidbey Island. It is about 8 miles by State Highway 1D north of Oak Harbor and a little over 1 mile southwest of Deception Pass Bridge.

Its main area (map, fig. 21) borders the south and west shores of Cranberry Lake, and a narrow strip extends southward for more than a mile. Its western border is a low ridge (bar) of beach sand and gravel less than a quarter of a mile wide, which lies between the peat area and Washington Sound, a part of the Strait of Juan de Fuca. The peat is shown as Greenwood peat and Rifle peat on the unpublished soil map of Island County (Ness and Richins). It is mapped as marsh on the Deception Pass quadrangle. An area of about 3½ square miles up to 400 feet in elevation is drained into the lake, but there is no surface outlet from the lake. A part, but not all, of the ridge separating the peat area from Washington Sound is more than 20 feet but less than 40 feet above mean low tide.

Some features which are important in determining the origin of the depression in which this peat lies are shown on Chart No. 6376 (Anacortes to Skagit Bay), U. S. Coast and Geodetic Survey. Rocks are shown at the junction of the shoreline of Washington Sound with the south shore of the open bay which leads to Deception Pass, and kelp is shown on the outer rock. The shallowness of the water along the shore of the sound is also shown. It is less than 2 fathoms deep (below mean low tide) for a distance of several hundred feet offshore.

It is possible to explain the origin of the depression and the formation and deposition of the peat in it by assuming that during postglacial times there has been gradual sinking of the land in the area with reference to sea level and it is also possible to account for it on the assumption that there has been no sinking.

On the basis of the latter assumption, the peat lies in what was once a salt-water bay which was later cut off from Washington Sound through the formation of a bar of sand and gravel by the action of current and waves. All that is known of this ridge is that it is composed of sand and gravel at the surface. It may be sand and gravel at depth, or it may be glacial drift or even rock or both. There is nothing inconsistent with the known facts, however, in supposing that it is composed of sand and gravel down to a depth of 50 feet, which corresponds to the depth of the peat.

The strong current of the Strait of Juan de Fuca sweeps northward along the shore of the northern part of Whidbey Island with the incoming tide, but there is comparatively little current there at outgoing tide. Thus at least the upper part and possibly all of the ridge terminating at the rocks at the north may have been built up by this northward-sweeping current since the retreat of the Vashon ice.

There is bedrock on both sides of Deception Pass, and this rock extends westward to within about 1,500 feet of the rocks at the north end of the gravel ridge (Glover, S. L., oral communication). This space of 1,500 feet has a mantle of glacial drift, the depth of which is not known.

The surface of the peat is practically at sea level, and the peat extends to a depth varying from 40 to 50 feet for a distance of more than 700 feet south of the lake. The plants growing on this peat, so far as they have been examined, are all freshwater species.

On the supposition that subsidence of the land has not been a major factor in the formation of the depression in which this peat lies, it may be assumed that the peat sank to its present position after it was formed in contact with a layer of fresh water which accumulated at the surface from drainage from the surrounding slopes and possibly from underground sources. It is well known that a layer of fresh water can accumulate over sea water with no mixing except for a slight amount at the level of contact. Plenty of fresh water has evidently drained into this depression in the several thousand years that have elapsed since the retreat of the Vashon ice. The precipitation in this region is moderate, however. The average annual precipitation at Coupeville, 9 miles south of this peat, for the 33 years preceding 1942 is 18.77 inches, and at Anacortes, 9 miles north of the peat, it is 26.5 inches for the 40 years preceding 1942.

The materials found in this deposit are sphagnum peat, fibrous peat, sedimentary peat, wood peat, peat slime, and clay. *Sphagnum* does not grow in salt water nor at such depths as the deeper layers of sphagnum peat now lie. One may reasonably suppose that it was formed in fresh water near the surface and sank to its present position. The sedge peat could have originated in the same way, but microscopic examination would be necessary in order to determine whether these materials originated in fresh water or salt water. This examination has not been made, but there is nothing in their macroscopic appearance or their physical properties that would distinguish them from such materials commonly found in peat deposits which are not close to salt water. The wood peat which is mixed with the fibrous peat at the bottom of hole 1 of the profile (fig. 21) probably originated from material washed in from the surrounding slopes. The wood peat at the 16- to 19-foot depths in hole 2 could have originated from shrubs or small trees growing on the surface of the peat and could have sunk to its present position. The clay found toward the bottom of hole 3 was evidently washed in. The formation of the peat slime, which is all at depths of 10 feet or less, is a common occurrence in the formation of peat adjacent to lakes.

The acidity of the water of Cranberry Lake near hole 1 and of the peat at various depths in hole 1 is comparable with acidities found in other lakes and in sphagnum peat adjoining them which are not close to salt water. The pH of the lake is 4.5. In sphagnum at the 1-foot depth it is 4.0, and at 11 feet in sphagnum it is 4.3. In sedimentary peat at 44 feet it is 6.2.

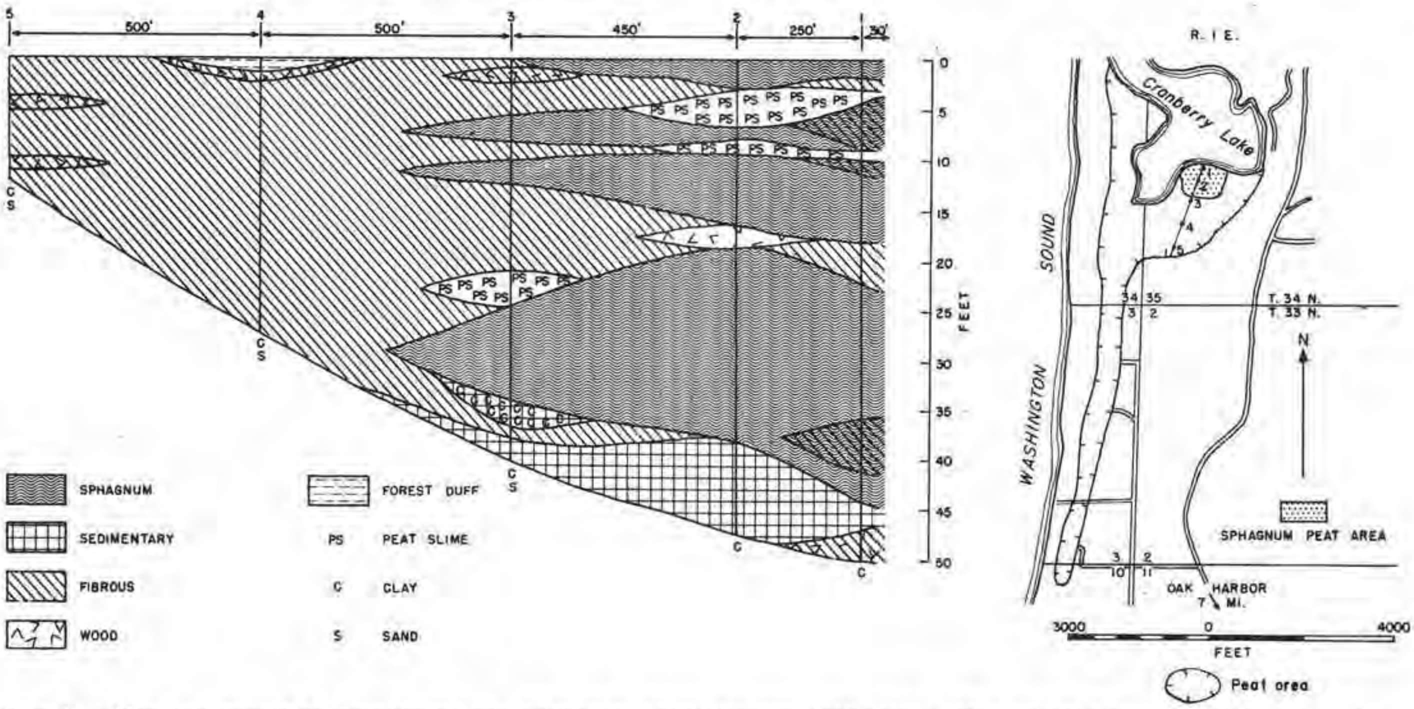


FIGURE 21.—Map and profile of Cranberry Lake peat area, Island County (180 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

No pumicite was found in boring this peat, though there is a layer of it in the Miller Lake peat near the south end of Whidbey Island, also in the peat area east of Miller Lake, and in several other inland bogs on the island. This absence of pumicite probably indicates that the deposition of peat at Cranberry Lake originated considerably later than at Miller Lake and that the former does not represent all of postglacial time.

It is also possible to account for the formation of the Cranberry Lake depression and the deposit of the peat in it on the assumption that during postglacial time there has been gradual sinking of the land surface with reference to sea level. Bretz (1913) found evidence for both emergence and submergence of the coast of Washington during and since glacial time. He indicated that the coast has been elevated as much as 1,000 feet above present sea level and at another time has been as much as 290 feet below present sea level. Though the latest event for which he saw evidence was emergence of the land, it must be remembered that evidences of emergence (e. g., wave-cut terraces) are much easier to detect than evidences of submergence. Drowned postglacially eroded valleys in glacial drift, however, are easily observed evidence of recent submergence, and J. H. Mackin (oral communication), has reported such valleys near Olympia.

The possibility that the peat deposits at Cranberry Lake, Swantown, Crockett Lake, Hancock Lake, and other places along the west shore of Whidbey Island show evidence of recent submergence of the land must be carefully considered.

If there has been subsidence at Cranberry Lake in postglacial time, the water in the depression may have been fresh during practically the entire time. The bar of sand and gravel may have been built up at approximately the same rate at which the land sank. In this case the various kinds of peat would have been formed in shallow fresh water as they are known to have been formed in many peat deposits in western Washington. This hypothesis is especially plausible in accounting for the deep fibrous peat in this deposit. This peat may be formed by the growth of sedges and similar plants from the substrate at the bottom of shallow water or by the sinking of mats of similar plants formed at the surface of the water.

This peat area is mostly covered with swamp forest, but a 19-acre area bordering the lake is sphagnum bog. The sphagnum bog has burned, and its most conspicuous feature now is a quantity of dead lodgepole pine trees. Seedling pines are numerous, and an examination of them indicates that the fire probably occurred in 1947 or 1948. It is well known that lodgepole pines drop viable seeds from old cones after a fire. The sphagnum bog has the characteristic herbs and shrubs, but it shows the effects of the fire. Some of the *Sphagnum* was killed, but some is spreading vigorously onto the burned places. Fireweed and pigeon wheat moss are fairly abundant. These commonly flourish in sphagnum bogs after a fire. The aerial parts of some of the Labrador tea and bog laurel plants were killed, but the plants are regenerating from uninjured stems and roots.

At its southern border the sphagnum bog merges into the swamp forest of medium-size western red cedar and other conifers. There are some alder and crab apple trees in the transition zone. Old down logs are numerous in this forest. The surface of the peat is very wet, and water stands on it in many places.

A conspicuous feature of the profile (fig. 21) is the presence of large amounts of sphagnum peat not only at the surface but also in deeper separate layers. Its color in the several layers varies from light brown to dark brown. At and near the surface it consists of whole stems with leaves still attached, but in the deeper layers it consists of detached leaves and short pieces of broken stems. Most of this disintegrated sphagnum is watery. The fibrous peat is brown to dark brown, and much of it is watery. As the holes were being bored, bubbles of marsh gas arose. The sedimentary peat is soft and has an olive color. The mixture of clay and sand under the peat is dark gray. The sand, where it occurs separately, is greenish gray, and the clay occurring separately is blue. No investigation was made of the long narrow southern strip mapped as peat.

The peat near the lake is deep. There are not many bogs in the state in which the peat is 50 feet deep, and very few in which there is so much sphagnum at such depths. Both the sphagnum peat and the sedge peat could be removed with a clamshell dredge operating from a barge. No evidence of any attempts at utilization was seen in this peat area.

Swantown peat area

The Swantown peat area (83 acres) is in sec. 32, T. 33 N., R. 1 E, about 3 miles northwest of Oak Harbor on Whidbey Island. It is just back of a ridge of gravel and boulders (map, fig. 22) along Washington Sound, which is a part of the Strait of Juan de Fuca.

It lies in a broad short valley which has a low gradient. The peat surrounds a small lake or pond. The stream which flows into the lake and out of it to Washington Sound originates some 3 miles to the southeast in a marsh at an elevation of about 110 feet and flows through another marsh on its way to the lake. As this stream has little erosive power, it has deposited little sediment in the lake. The broad, relatively flat valley in glacial drift evidently was developed prior to Vashon glaciation. The physical features of the region are shown on the Deception Pass quadrangle. The unpublished soil map of Island County (Ness and Richins) shows Tacoma muck and Mukilteo peat in this area.

The peat area is cut off from the tidewater of the sound by a ridge of gravel and boulders which rises to a height of about 6 feet above high tide. Beyond this is a shelving sandy beach, and the sound is shallow off shore. There is a sea cliff 260 feet high just south of the peat area, but the land along the shore to the north of the peat is flat to gently sloping. The sea cliff is composed of flat-lying beds of sand and finer materials with a mantle of till 3 to 8 feet thick lying uncomformably over them. The till is composed largely of fine materials, but there are some boulders and gravel scattered through it. The till sheet extends to and probably across the valley floor.

It seems evident that the ridge of gravel and boulders has been developed by the action of waves and current

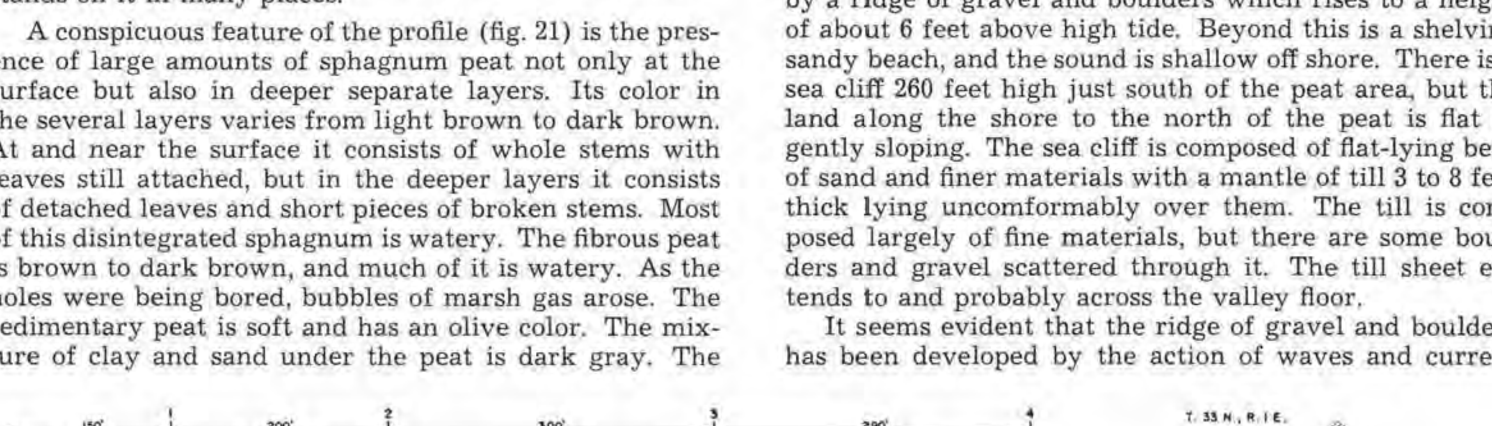


FIGURE 22.—Map and profile of Swantown peat area (83 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

on this till. Winds blowing over the Strait of Juan de Fuca raise waves, and the strong current of the incoming tide from the strait sweeps northward along the shore, but there is comparatively little current here on the outgoing tide. Thus the ridge is formed from the coarser materials by the sorting action of the water, and the shelving beach is formed from the finer material.

The stream from the lake to tidewater has been artificially deepened to form a drainage ditch. A check valve permits water to flow out at low tide but prevents sea water from flowing in at high tide. The area of the lake has thus been considerably reduced. The native vegetation on the peat consists of salt-marsh plants. Salt grass is dominant in some places and glasswort in others. The peat encountered in boring (fig. 22) is all fibrous except near the lake, where it is sedimentary from the 1-foot level to the bottom and a mixture of fibrous and sedimentary from the 1-foot level to the surface.

The materials encountered in the borings in this peat vary from weakly acidic to neutral. In hole 1 the pH of the fibrous peat at the 1-foot depth is 5.0, and at 4 feet it is 6.0. In hole 4 the pH of the mixture of fibrous and sedimentary peat at the 1-foot depth is 6.0, and the bare mud nearby is neutral (7.0). These determinations are consistent with the theory that this peat was formed in brackish water.

The physical properties of this peat and the macroscopic characteristics of the plant remains forming it do not indicate whether it was formed in salt water or fresh water, and no microscopic examination has been made. The physiographic conditions and the present living vegetation, however, indicate that it was formed in salt or brackish water. The average annual precipitation at Coupeville, which is about 4 airline miles southeast of this peat, for the 33 years for which records have been kept, is 18.77 inches. With this low rainfall on the small drainage basin, the volume of water coming into this depression annually is not large.

The surface of this peat is not far above sea level (mean low tide), and at the deepest point in the profile the bottom of the peat, which rests on sand and clay, is about 10 feet below low tide. There is nothing inconsistent in supposing that at the retreat of the Vashon ice this depression was a shallow bay of salt water and that this was gradually cut off by the building up of a bar of sand, gravel, and boulders by the action of current and waves. The configuration of the coast, the presence of the sea cliff, and the direction of the shore current are all consistent with this view. There is, however, nothing in these considerations which is inconsistent with the theory that there has been gradual sinking of the shore in postglacial times.

Some of this peat area toward the margin, where the elevation is slightly greater, is utilized for crops and pasture. There is some salt grass on much of the peat area, and cattle pasture on it. The prospects for extending the area of utilization do not seem very bright. It would be possible to remove the brackish water from the pond by pumping, but if this were done, sea water probably would percolate in through the bar and refill the lake up to approximately its present level.

Crockett Lake peat area

The Crockett Lake salt marsh peat area (792 acres) is in secs. 13, 14, 15, 22, 23, and 24, T. 31 N., R. 1 E., on the west coast of Whidbey Island. It is 2.4 miles by paved road south of Coupeville. The old slip of the Keystone Ferry to Port Townsend was near the eastern part of the peat area, but the new slip is in an excavation which has been made at the west end of the area. The Fort Casey Military Reserve borders the west side and part of the north side of the area. The peat area is about 2½ miles long and is more than half a mile wide at its widest point. It is shown as tidal marsh on the unpublished soil map of Island County (Ness and Richins).

Crockett Lake has been drained to Admiralty Inlet, and in July 1951, at low tide, water was still flowing from the pipe at the mouth of the ditch. A check valve prevents sea water from flowing in at high tide. The present lake has only a fraction of the area of the lake before drainage. Evidently the lake was originally formed by the building up of a gravel ridge along its south side by the action of current and waves.

The vegetation on this peat (fig. 24) consists mostly of salt-marsh plants. The dominant species in the western part is glasswort (samphire or salthorn) which is unsuitable for pasture, but in the extreme eastern part there is some salt grass, which furnishes good pasturage. At hole 4 in profile B, where the deepest peat is found, tules and silver weed (goose tansy) are the main species. These two are not characteristic of salt marshes, though silver weed does often grow near them. There are also some tules at hole 1 in profile C. Hole 5 in profile B was bored in a pasture in which grasses and weeds grow.

Most of the peat in this deposit is fibrous. Much of it is watery. Its color varies from light brown to dark brown. A considerable amount of the peat consists of intact fibers, but some is disintegrated and some is decomposed. A strong odor of hydrogen sulphide came from the hole which was bored near the lake (Hole 1, profile A). The sedimentary peat from the 2-foot to the 3-foot depth in profile A is black; the mixture of sedimentary and fibrous peat in hole 4, profile B is brown; and the sedimentary peat at the bottom of hole 3 in profile B is dark brown and watery.

The peat in this area is neutral or only mildly acid. This is to be expected in peat which is saturated with brackish water. Nine determinations were made of the pH of samples at depths of 1 to 13 feet from four holes in profile A, four in profile B, and one in profile C. One was neutral (pH 7.0), five were mildly acid (pH 6.0 to 6.5), and the other three ranged from 5.0 to 5.5.

The peat in this deposit is salty, and the plants which have grown on the surface laid bare by drainage are salt-marsh plants. A drainage district has been organized and assessments levied to pay the expenses. The drainage is going on successfully. The water could be removed from the lake by pumping. It is evident, however, that time must elapse before the soil will be sufficiently free from salt to produce profitable crops. There is some utilization of parts of this peat area for pasturage and also of other parts for cultivated crops, but such utilization is small.

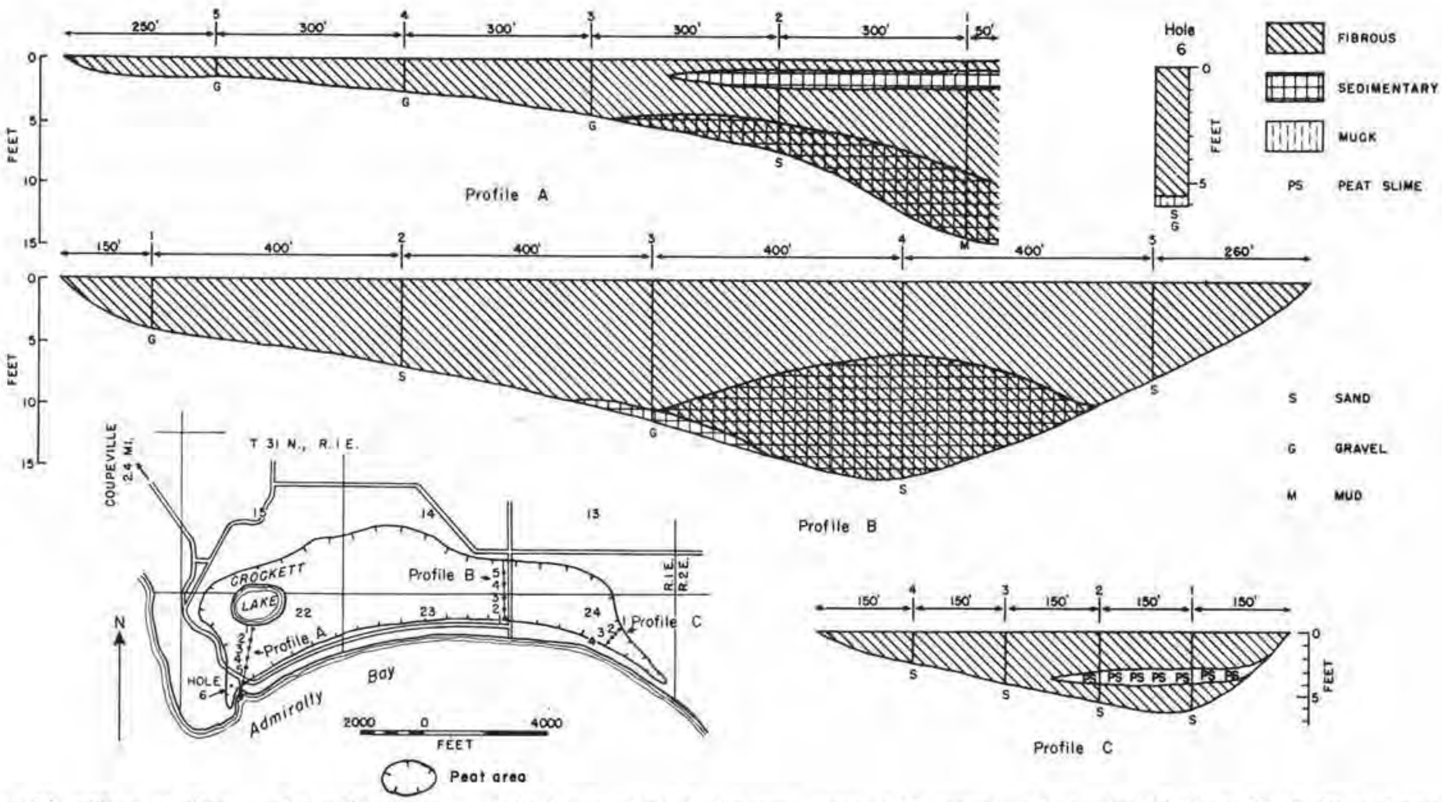


FIGURE 23.—Map, profiles, and graphic log of a hole in Crockett Lake peat area (792 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

FIGURE 24.—Drained salt marsh peat deposit, Crockett Lake. The clumps of vegetation are *Salicornia*.

In considering the problem of future utilization, the fact that salt-marsh vegetation is now growing on the part laid bare by drainage must be taken into account.

Hancock Lake peat area

The Hancock Lake peat area (202 acres) is in secs. 5, 6, 7, and 8, T. 30 N., R. 2 E., on the west coast of Whidbey Island. It is 11 miles south of Coupeville on State Highway 1D. It is shown as tidal marsh on the unpublished soil map of Island County (Ness and Richins). There is a "lake" of brackish water in the eastern part of the area, and this is connected with tidewater (Admiralty Inlet) by a narrow channel about 1,500 feet long. The slopes north and east of the area are comparatively steep. A gravel bar separates the peat area from Admiralty Inlet.

The salinity of a sample of water taken from the south margin of the "lake," determined by Dr. T. G. Thompson, of the Oceanographic Laboratories of the University of Washington, was 30.34 parts per million. The average salinity of the waters of the Pacific Ocean at 40° N. latitude is 33.64. Insofar as these data indicate, the salinity of the water of the "lake" is 90.2 percent of that of sea water, so the "lake" is really a brackish lagoon.

Two peat samples were taken from hole 3 of profile B, and determinations were made on them in the State Department of Agriculture laboratory at the University of Washington (nos. 46, 47, p. 254). The chlorine content of the sample from the surface to the 1-foot depth was 5.3 percent of the dry weight, and that of the one from the 5- to 6-foot depth was 13.5 percent. In comparison with these data, determinations made on 45 samples taken at various depths in bogs in various parts of the state showed a maximum chlorine content of 0.083 percent and a minimum of 0.002 percent. The sample from the first foot of the Hancock Lake area thus shows over 63 times as much chlorine as the highest chlorine content found in peat elsewhere in the state, and the sample from the 5- to 6-foot depth shows 162 times as much chlorine as has been found in any other peat in the state. As these data indicate the percent of chlorine in the dried peat, they cannot be compared directly with the salinity determination on the water of the lagoon. However, the high chlorine content of this peat is undoubtedly due to the influence of sea water, and it is probable that the salt content of the Hancock Lake peat is very high.

Only the part of the area lying south of the lagoon and the channel which connects it with tidewater was examined. The vegetation on this area is of four different types—salt marsh, fresh-water marsh, sphagnum bog, and swamp forest. There is a gradual transition from one to another where they border each other, and there are thus no sharp boundaries. The salt-marsh area is the largest. It lies between the lagoon and Admiralty Inlet and also borders the lagoon on the south. It has the usual salt-marsh vegetation. Glasswort is the most abundant plant on most of the area, but salt grass is dominant in some places. The freshwater marsh lies along the southeast shore of the lagoon. The most prominent plants in it are cattails and sedges.

The sphagnum bog lies along the line of profile A and extends some distance on both sides of it. It still has some living *Sphagnum* in spite of several fires and has the usual bog shrubs and herbs. The rather extensive swamp forest extends across the southern part of the area south of the sphagnum bog and ends at the slightly higher land at the south where better forest begins. The trees in the swamp forest are mostly cedar and hemlock, but there is some lodgepole pine in the northern part and some alder in the southern part.

There are dead, fire-blackened trunks of lodgepole pine trees on much of the salt marsh and the sphagnum bog. This indicates that an extensive fire occurred several years ago. There is evidence, also, of a more recent fire in the sphagnum bog, where sphagnum to a depth of about 1 foot has burned.

Two profiles and one other hole were bored in this

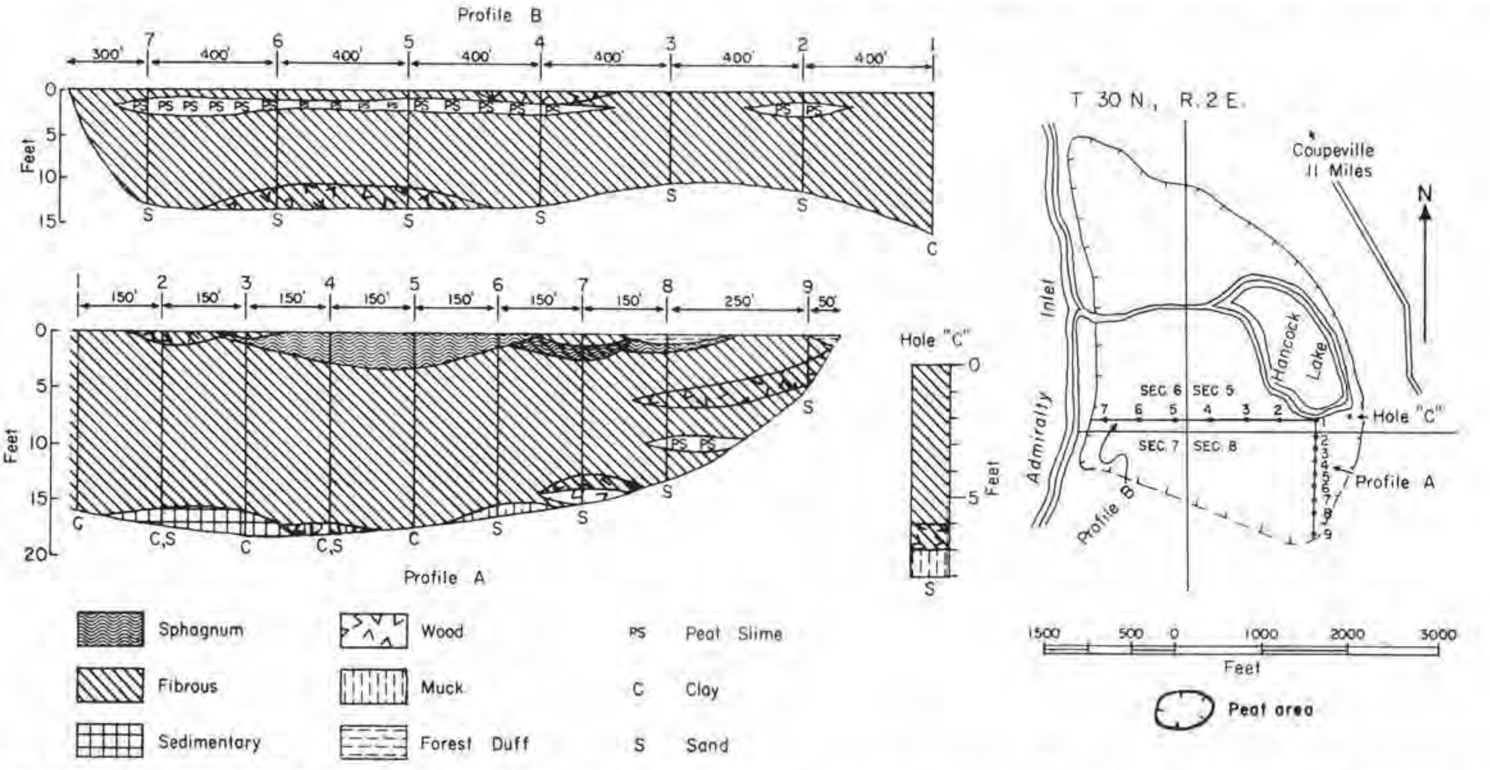


FIGURE 25.—Map, profiles, and graphic log of a hole in Hancock Lake peat area (202 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

peat (fig. 25). The fibrous peat, which constitutes by far the largest part of the materials found in profile A, is light brown to dark brown. Some of it is raw, and some is disintegrated. In the salt marsh the fibrous peat within 2 feet of the surface has a salty taste, but in material below that depth there is no salty taste. Bubbles of hydrogen sulphide arose from hole 2 during the boring. Digging at hole 1 and 500 feet west disclosed numerous rhizomes of bracken fern, which makes it evident that a community of fresh-water plants flourished there before the present salt-marsh community came in.

The sphagnum found at holes 4, 5, and 6 is light brown to dark brown. Near the surface it consists of intact leafy stems, but at the 3-foot depth it is disintegrated. The small amounts of sedimentary peat, wood peat, and muck lying at the bottom in this profile have the usual characteristics of these materials. There is clay at the bottom of holes 1 to 5 and sand at the bottom of holes 6 to 10.

At profile B there is flourishing salt-marsh vegetation at holes 1 to 6, inclusive, and in their vicinity. There is also some scattered salt-marsh vegetation in the vicinity of hole 7, but most of the surface there is bare. The fibrous peat in this profile is in general similar to that in profile A. Bubbles of hydrogen sulphide gas arose from various depths in some holes in this profile. The presence of peat slime (fig. 25) at moderate depths in this profile is consistent with the general watery character of the peat. Clay under the peat is more extensive south of the

FIGURE 26.—A burned peat area (Hancock) in Island County with charred snags still standing. Photo by M. A. Bender.

lake than southwest of it. There is clay at the bottom of holes 1 to 5, inclusive, in profile A; whereas in profile B there is sand at the bottom of all holes except No. 1, which is the same hole as hole 1 of profile A. In hole C, which is in the fresh-water marsh, the watery fibrous peat is brown and the muck is black. Coarse sand occurs at the bottom.

The peat in the Hancock Lake deposit at various depths, as indicated by 6 determinations in profile A and 14 in profile B, varies from weakly acidic (pH 6.2) to rather strongly acidic (pH 4.3). The average acidity in profile A (pH 4.9) is somewhat higher than in profile B (pH 5.6). This would be expected, because the determinations in profile A were made on material from holes which were bored either in or close to sphagnum-bog vegetation, while those in profile B were made on material from holes bored in salt-marsh vegetation. There was a slight increase in acidity with depth in holes 5 and 6 of profile B, the reverse of the condition usually found in peat deposits. It indicates the effect of the presence of salt water in the later stages of the development of this part of the peat deposit.

Miller Lake peat area No. 1

The Miller Lake peat area No. 1 (240 acres) is in secs. 16, 21, 22, and 28, T. 29 N., R. 3 E., on the southern part of Whidbey Island (map, fig. 27). It is a little over 3 miles by road south of Langley and about the same distance west of Columbia Beach. State Highway 1D passes near the peat. The peat area is shown as Mukilteo peat on the unpublished soil map of Island County (Ness and Richins).

The peat surrounds Miller Lake. There is an "island" of hard land in the south arm of the peat area and a small sphagnum bog at the tip of the southwest arm. Some small streams flow into the lake, and a small stream flows from the south end of the lake to Admiralty Inlet.

There are some hayfields, some pastures, and some waste land on this peat area. Some of the waste land is swampy.

The fibrous peat, which is the principal material found in the profile (fig. 27) is mostly rather watery and varies from light brown to dark brown and from raw to disintegrated. A few feet under the surface it is comparatively loose, but at greater depths it is compact. The sedimentary peat at the 40-foot depth in hole 3 is too compact to be penetrated deeper with the peat borer. Pumice in this peat is brown and white and forms a layer ½ to 1 inch thick. The peat rests on sand which ranges from gray to blue gray.

The small sphagnum bog (map, fig. 27) is very dry, and the only characteristic bog species found there now is Labrador tea. The present dry condition is probably due to clearing and drainage, and also trampling by domestic animals. The sphagnum is dry and the fibrous

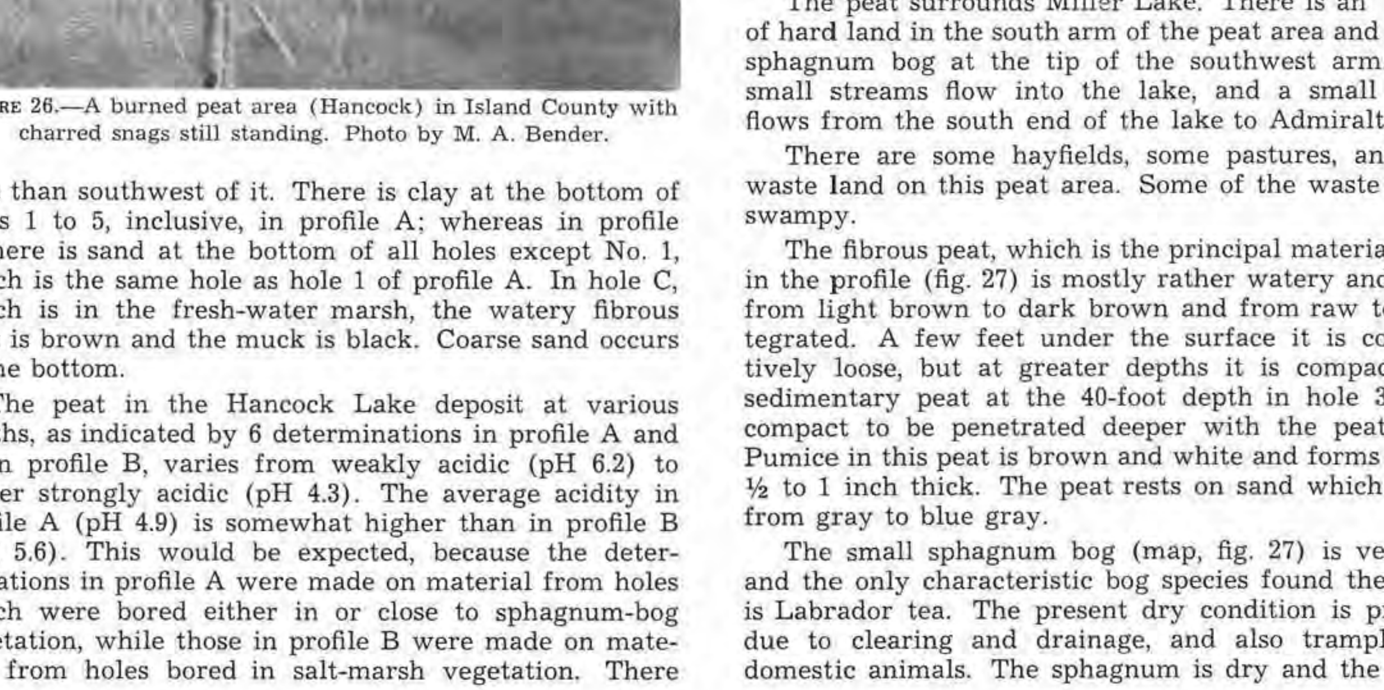


FIGURE 27.—Map, profile, and graphic logs of two holes in Miller Lake peat areas, Island County (240 acres and 97 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

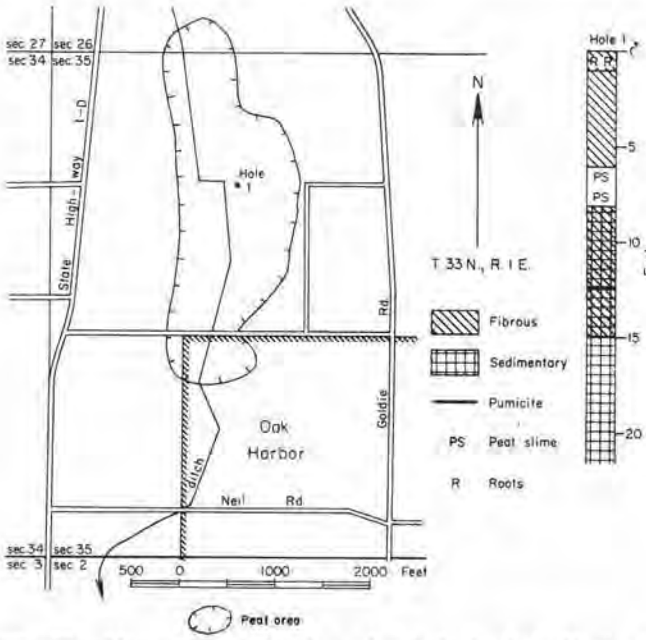


FIGURE 28.—Map and graphic log of a hole in Oak Harbor peat area (99 acres). Map adapted from sketch by B. Ronhaar and U. S. Army Map Service photomosaic.

peat is compact. Charred materials at the 3-, 4-, and 6-foot depths record fires on the bog long ago.

The peat in hole 2 in the profile is strongly acidic (pH 3.8) at the 1-foot depth and rather weakly acidic (pH 5.5) at the 38-foot depth.

The surface of the peat in the hayfields and pastures in the vicinity of the profile is firm, though the peat is deep. Domestic animals find good footing in the pastures, and mechanical equipment is used in the hayfields. This is the deepest peat being utilized for agricultural purposes that has been found in the state. At hole 3, which is in a hayfield, the peat is 40 feet deep, and at that depth it is too compact to be penetrated farther with the peat borer.

Miller Lake peat area No. 2

This peat area (97 acres) lies to the east of Miller Lake in secs. 15 and 22, T. 29 N., R. 3 E. (map, fig. 27). It is very irregular in shape, and at the nearest point it is only 600 feet from the border of Miller Lake peat area No. 1. Two streams flow across it and unite into a stream which flows into Miller Lake. The area is shown as Mukilteo peat on the unpublished soil map of Island County (Ness and Richins).

There is much waste land on this peat, but there is some pasture land. There are many small stumps and old logs in the pasture. The living vegetation consists of pasture grasses, weeds, and swamp plants. Wood peat (fig. 27) is mixed with the fibrous peat at four different levels. This peat, like that in Miller Lake peat area No. 1, lies in a depression in glacial drift. Brown pumicite forms a layer 2 inches thick. The position of the layer of pumicite makes possible a comparison of the stage of development of the two peat deposits at the time of the fall of the ash. The peat in Miller Lake area No. 1 is deeper, and the pumicite in it is at deeper levels, though in hole 1 it is only about 1 foot deeper.

Oak Harbor peat area

The Oak Harbor peat area (99 acres) is in secs. 26 and 35, T. 33 N., R. 1 E., on Whidbey Island. Most of it lies just north of the city limits of Oak Harbor, but the southern tip (10 acres) is inside the city limits (map, fig. 28).

It is drained by a ditch from which water flows through a 12-inch tile to the salt water of Oak Harbor at the south city limits. Water flows freely in the ditch and through the tile during the wet season, and drainage is effective. The present ditch was dug in 1948 by the man who at that time owned the entire tract. The first ditch was dug about 1918 by an earlier owner, but the concrete tile used disintegrated in the course of time, and the peat was flooded, necessitating redigging the ditch and putting in new tile.

Most of the area has been cleared, some of it very recently, but some trees and brush still remain. Part of the area is utilized for truck gardens and pastures, but there is still some waste land. It is now owned by eight persons, whose holdings vary from 3 to 27 acres. The largest tracts are owned by Benj. Rohnhaar (27 acres) and H. Hilberdink (25 acres).

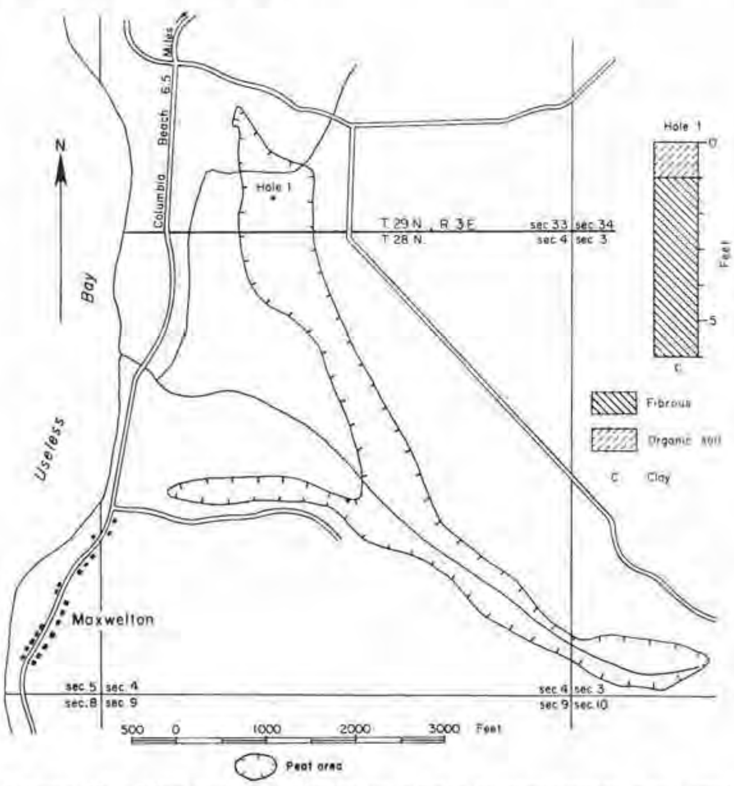


FIGURE 29.—Map and graphic log of a hole in Maxwelton peat area (118 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

One hole, 1,600 feet north of the city limits and about 150 feet east of the ditch, was bored to a depth of 21½ feet (fig. 28), but the olive-brown sedimentary peat at that depth was so compact that it prevented deeper boring. The fibrous peat at the surface is distinctly yellow, but it merges to brown at a depth of less than 2 feet. The layer of white pumicite is 1 inch thick.

Maxwelton peat area

The Maxwelton peat area (118 acres) is in sec. 33, T. 29 N., R. 3 E., and secs. 3 and 4, T. 28 N., R. 3 E., near the southwestern shore of Whidbey Island. It is about 5 miles by road southwest of Columbia Beach. The area is long and narrow (map, fig. 29). The western tip of its west arm is about half a mile northeast of Maxwelton and about 800 feet from the tidewater of Useless Bay. It is mapped as Mukilteo peat and Rifle peat on the unpublished soil map of Island County (Ness and Richins). A stream flows through the entire length of the southeast arm and into Useless Bay, and a tributary stream flows across the north arm.

One hole bored in a pasture in this peat shows 1 foot of peat soil and 5 feet of fibrous brown peat (fig. 29) which has a very pronounced odor of decay. The vegetation at this hole consists of pasture grasses and rushes with a few cattails and some weeds. The peat rests on gray clay.

Mutiny Bay peat area

The Mutiny Bay peat area (60 acres) is in the SW¼ and the SW¼NW¼ sec. 9, T. 29 N., R. 2 E., on the southwestern shore of Whidbey Island. It comprises most of the area that lies within the 20-foot contour line as shown on the Freeland quadrangle. It is about 1 mile west of Freeland, and its southern border is about 300 feet from the tidewater of Mutiny Bay. The southern part of the area is salt marsh, and the northern part is swamp forest. This peat is very shallow. The deepest boring shows 1 foot of fibrous peat and 1 foot of woody peat, below which is sand. The unpublished soil map of Island County (Ness and Richins) shows Tanwax peat and Tacoma muck in this area.

Glendale peat area

The Glendale peat area (34 acres) is in sec. 35, T. 29 N., R. 3 E., on Whidbey Island. It is about 2 miles northwest of Glendale, which is on Possession Sound, and about 3 miles southwest of Clinton (map, fig. 30). It is shown on the unpublished soil map of Island County (Ness and Richins) as Greenwood peat and Mukilteo peat. A stream flows south through the eastern part of the area to Possession Sound.

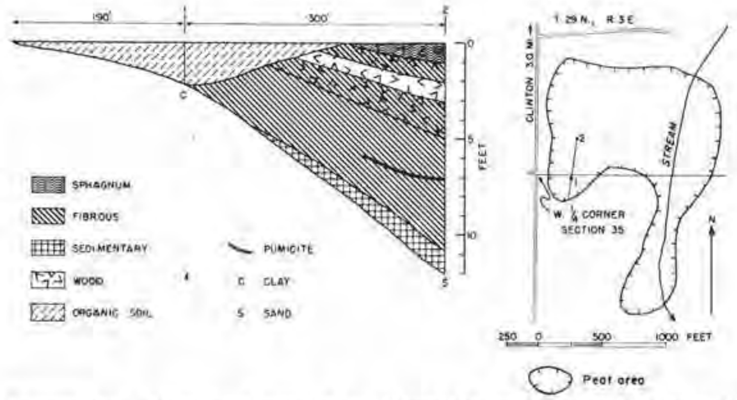


FIGURE 30.—Map and profile of Glendale peat area (34 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

The vegetation on the western part of the area consists mostly of hardhack brush, bracken ferns, and fireweed. There is some old dry sphagnum, but no living *Sphagnum* was seen. Fibrous peat and wood peat are the principal materials (fig. 30). The pumicite is brown and is in a layer 1 inch thick. There is some charred material mixed with clay at the bottom of hole 1. The olive-colored sedimentary peat at the bottom of hole 2 is compact and contains some fibers. The peat rests on sand.

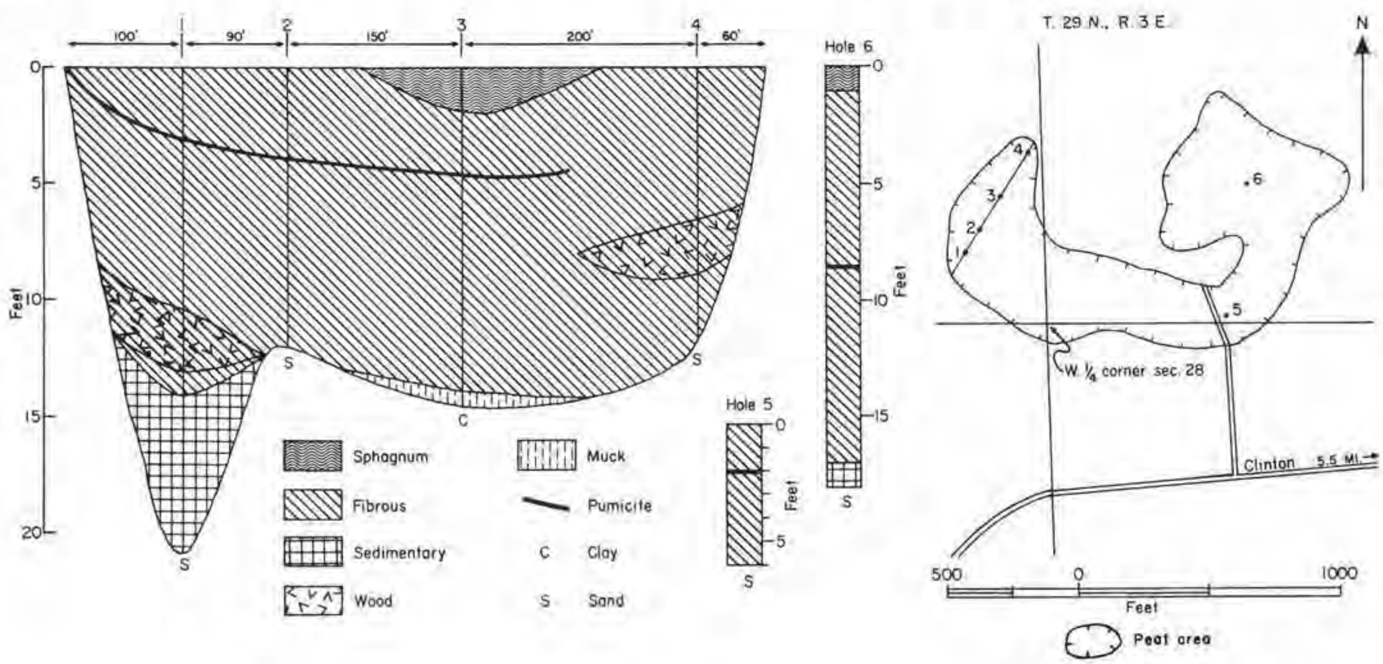


FIGURE 31.—Map, profile, and graphic logs of two holes in Hillberg peat area (17 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

Hillberg peat area

The Hillberg peat area (17 acres) is a sphagnum bog in secs. 28 and 29, T. 29 N., R. 3 E., on Whidbey Island, about 6 miles by road west of Columbia Beach. At the nearest point on its boundary it is about half a mile east of the tidewater of Admiralty Inlet. It lies in an undrained depression in glacial drift. An old unimproved road leads north from the county road to the bog, and an old corduroy road crosses the bog. It is mapped as Mukilteo peat on the unpublished soil map of Island County (Ness and Richins).

It has the usual sphagnum-bog flora of herbs and shrubs, including the small creeping woody vines of the native cranberry, with abundant living *Sphagnum* and other mosses. There are some willows and hardhack in the margins, some hardhack and bracken ferns on the bog, and in some of the wetter places there are sedges, rushes, and cattails.

Sphagnum peat is found only in holes 3 and 6 (fig. 31). In hole 3 it is raw and brown and contains some fibers of other plants and also some wood. In hole 6 it is not mixed with any other materials. Most of the peat in this deposit is fibrous. It varies from light brown to brown, from raw to decomposed, and from loose to compact. Some of it is watery. The sedimentary peat is olive green to olive brown and contains some fibers, wood, and sand. The layer of brown pumicite is ½ inch to 2 inches thick. The peat rests mostly on gray to greenish-gray sand, but gray clay is present at the bottom of one hole.

No evidence of attempts at utilization of the peat in this bog was seen.

Roadside peat area

The Roadside peat area (11 acres) is in sec. 17, T. 29 N., R. 3 E., on Whidbey Island, about 5 miles northwest of Columbia Beach. It borders the south side of State Highway 1D and lies in a depression in glacial drift (map, fig. 32). It is mapped as Mukilteo peat on the unpublished soil map of Island County (Ness and Richins).

This is an old sphagnum bog which shows evidence of a fire a few years ago. It is very dry now, and there are only a few patches of living *Sphagnum*. Labrador tea is the only other surviving sphagnum-bog plant, though there is some hardhack brush. Bracken ferns and pigeon

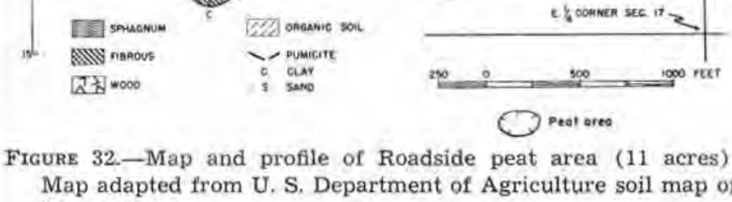


FIGURE 32.—Map and profile of Roadside peat area (11 acres). Map adapted from U. S. Department of Agriculture soil map of Island County.

wheat moss occur; they are characteristic of burned sphagnum bogs. There are some small scattered white pine trees and a few small, stunted Douglas firs.

This peat deposit (fig. 32) is practically all fibrous peat which is rather strongly acid (pH 3.5 to 4.2). It is mostly decomposed, but some of it is raw. There is some charred material at the 2-foot level and also at the 11-foot level. A layer of brown pumicite is 1 inch thick. At the bottom is sand. The amount of sphagnum peat is too small to be of any importance.

Clinton peat area

The Clinton peat area (6 acres) lies near the southeast corner of sec. 23 and the southwest corner of sec. 24, T. 29 N., R. 3 E., on Whidbey Island. It is on the south side of State Highway 1D about 1 mile west of Clinton. It is mostly logged-off land on which willows, hardhack, elderberry bushes, and sedges grow. A stream flows eastward through its entire length. One hole in sec. 24 shows from top to bottom: 1 foot of black muck, 1 foot of fibrous peat, 1 foot of mixed fibrous and wood peat, 2 feet of fibrous peat, 1 foot of mixed fibrous and wood peat, and 3½ feet of fibrous peat overlying a mixture of clay and sand.

This peat deposit was excavated and destroyed in 1953 during reconstruction of the highway that paralleled the area.

Taylor peat area

The Taylor peat area (9 acres) is in sec. 20, T. 33 N., R. 2 E., on the farm owned and occupied by Walter Taylor on Whidbey Island. It is about 1¼ miles southeast of Dugualla Bay and about 5 miles by road northeast of Oak Harbor. On the unpublished soil map of Island County (Ness and Richins) the north 9 acres is mapped as Greenwood peat and the south 10 acres as Tanwax peat.

The Greenwood peat is covered by a bog forest of lodgepole pine with an undergrowth of Labrador tea. Some of the trees are 30 feet or more tall. There are some patches of living *Sphagnum*, and there is some sphagnum peat. No borings were made.

The Tanwax peat is mostly covered with a rather dense growth of hardhack and sedge with some rushes. A natural ditch, in which some water stands or flows in wet weather, crosses the peat. Digging in the bottom of this ditch revealed 3 feet of a black mixture of muck and fibrous peat, but bottom was not reached. There is a layer of white pumicite 2 inches thick at the 16-inch depth. Some of the muck-peat mixture has been removed near the ditch and used on neighboring gardens.

Dugualla Bay area

On the soil survey of Island County (Carr and Mangum, 1906) a peat and muck area is shown extending around the shore of Dugualla Bay. This is now diked land, and some of it is in cultivation. Inquiry among farmers living south of the bay did not indicate the existence of any peat, but the existence of peat in waste places cannot be excluded, as a thorough investigation was not made. The nearest approach to peat seen is an area of 15 acres bordering the high land at the south side of the bay. In this area the soil to a depth of 12 to 18 inches is a mix-

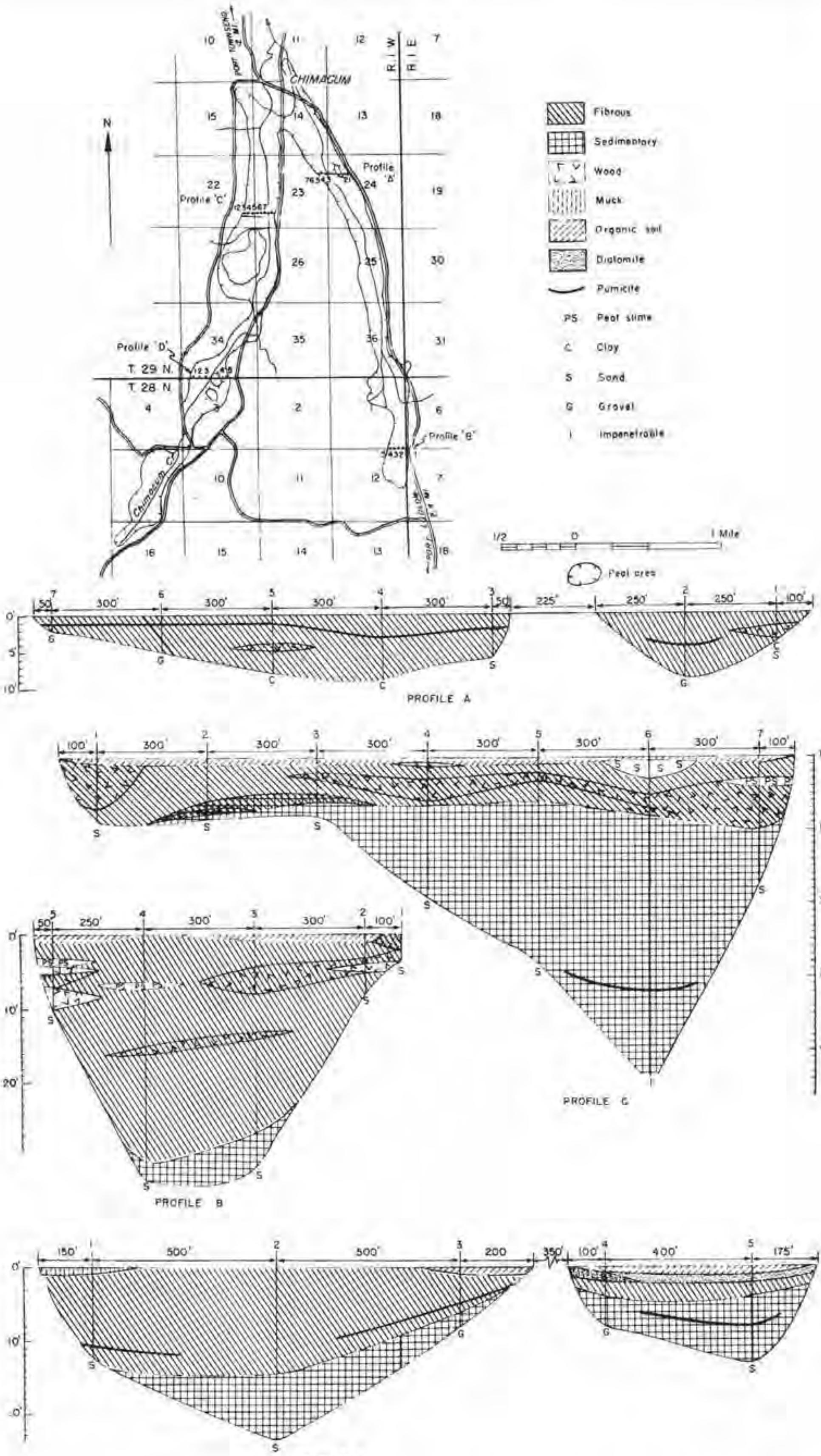


FIGURE 33.—Map and profiles of Chimacum peat area (2,605 acres). Map adapted from U. S. Army Map Service photomosaic and U. S. Department of Agriculture soil map of western part of Puget Sound Basin.

ture of organic and mineral matter. It is utilized for growing oats or hay. There may be peat at the head of the bay. This area was not investigated.

JEFFERSON COUNTY DEPOSITS

Chimacum peat area

The Chimacum peat area (2,605 acres) lies in 20 sections of T. 29 N., R. 1 W.; T. 28 N., R. 1 W.; T. 29 N., R. 1 E.; and T. 28 N., R. 1 E. (map, fig. 33). It is in the northeastern part of the county, about 6 miles south of Port Townsend. The town of Chimacum is close to its northern end.

In general, the surface of this part of the county consists of glacial drift and shows a rolling topography. The elevation at Chimacum is 250 feet above sea level. The peat area consists of two arms, each of which is elongated and irregular in shape (map, fig. 33). The west arm is over 6 miles long and contains three "islands" of hard land. The east arm is only slightly shorter and contains one "island." Chimacum Creek flows north through the entire length of the west arm to the tidewater of Port Townsend Bay. A branch of this stream originates not far from the southern end of the east arm and flows north through the peat to join the main stream north of the peat area.

The two branches of this creek carry off the surface water during the comparatively dry summer season, but during the winter and spring there is some flooding, and strong currents are developed. The peat area is so flat that the drainage provided by the two branches of the creek and their small tributaries is inadequate. In spite of the drainage ditches which have been dug, the soil still contains so much water that this is a limiting factor in agricultural utilization.

Considerable portions of this peat area are utilized for pasture and for the production of oats and hay. Some of the area is waste land, which is covered in some parts by woody growth and in others by herbaceous plants. The woody growth is composed mainly of willows, hardhack, young alder trees, and some small shrubs. The herbaceous growth in some parts of the area consists of swamp species such as sedges, rushes, dock, and even skunk cabbage, while in other places the characteristic vegetation consists of bracken fern, thistles, scouring rush, and some grasses.

The strata in the peat (fig. 33) are fibrous peat, sedimentary peat, wood peat, muck, diatomite and pumicite. The depression in which the peat lies was formed by the action of water and ice during glaciation in Pleistocene time. When drainage to the north was cut off by the blocking of the channel by debris deposited by the retreating ice front, the depression filled with water. The 24 borings in the four profiles in this peat area indicate that the bottom of the depression was very irregular and consisted mostly of sand and gravel with some clay.

The layer of pumicite shown in the profiles varies in thickness from 1/16 inch to 1 inch. When this pumicite fell, part of the area now covered by peat was a lake, and the pumicite which fell on the surface of the lake sank to the bottom; it is now both overlain and underlain by peat. The amount of pumicite in this peat area is of course too small to modify the character of the peat to any appreciable extent.

Field determinations of pH indicate that the acidity of the peat in profiles A and B, which are in the east arm of the area, is within the usual range of acidity of peat in western Washington. The acidity in profiles C and D, which are in the west arm, is low, being comparatively close to neutral. Six determinations in profiles A and B on samples taken at depths ranging from 1 foot to 29 feet show an average pH of 5.0. The minimum (4.2) occurs at the 1-foot depth, and the maximum (5.5) occurs at 25 and 29 feet. Three determinations in profiles C and D, two of which are on samples taken at a depth of 6 feet and one at 43 feet, show an average pH of 6.4. The last of these has a pH of 6.5; the other two are 6.5 and 6.2.

This peat area is in a region of relatively low precipitation. The average annual precipitation at Port Townsend over a period of 40 years is 17.38 inches. At Chimacum over a period of 12 years it is 21.75 inches.

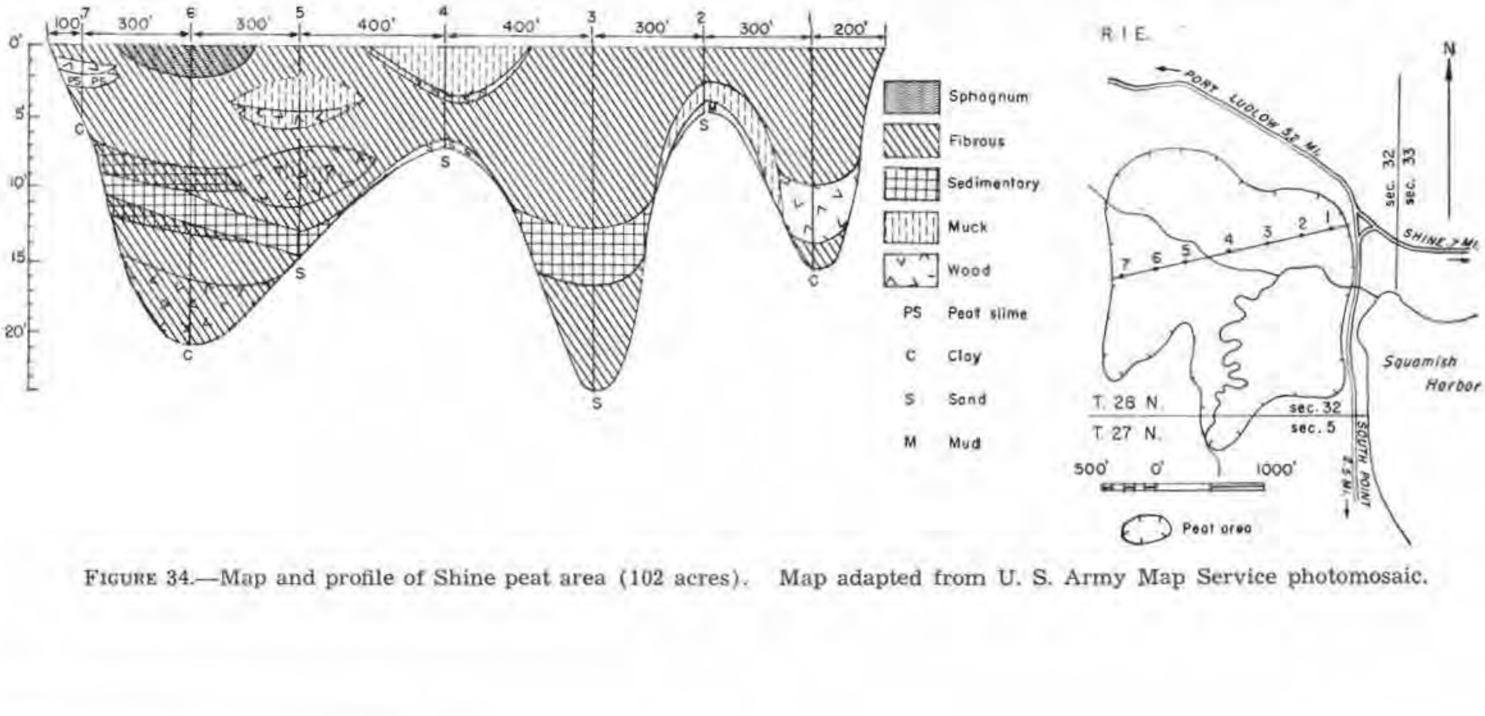


FIGURE 34.—Map and profile of Shine peat area (102 acres). Map adapted from U. S. Army Map Service photomosaic.

Shine peat area

The Shine peat area (102 acres) is in the northeastern part of the county, about 5 miles southeast of the south end of the Chimacum peat area. It lies in sec. 32, T. 28 N., R. 1 E., and sec. 5, T. 27 N., R. 1 E., and is about 4 miles south of Port Ludlow and ½ mile west of the village of Shine. The border of the peat area is about 200 feet from the shore of Squamish Harbor, which is a part of Hood Canal.

The depression left when the Cordilleran ice retreated was irregular in depth, as is indicated by the profile (fig. 34). Clay was found below the peat at both ends of the profile (holes 1, 6, and 7), but sand was encountered at the bottom of the intervening holes. The highway, which is on an earth fill between the margin of the peat and the salt water of the harbor, has practically obliterated the natural conditions there. Two streams, which originate in the neighboring upland, unite in the peat area, and the sluggish stream thus formed flows on across the peat area and into Squamish Harbor.

The drainage provided by the streams is not adequate to remove excess water from the peat. The peat area at present is partly sphagnum bog, partly swamp which bears herbaceous vegetation, and partly swamp forest. In some places the present vegetation indicates the influence of salt water. It is probable that before the highway fill was put in there was a gradual transition from bog vegetation to salt-marsh vegetation. *Sphagnum* covers some of the surface of the bog, but no pure sphagnum peat is present. A mixture of sphagnum peat and fibrous peat is present at hole 6.

Two pH determinations (6.5 and 6.9) indicate that this peat is only slightly acidic. No evidence of attempts at agricultural utilization of this peat was seen. Small quantities of peat moss (sphagnum) could be obtained for local use by tedious handpicking.

Forks peat area

The Forks peat area (18 acres) is in secs. 17 and 18, T. 27 N., R. 12 W., in the northwestern part of Jefferson County. It occupies a shallow depression in an old drainage way south of the Olympic Highway (U. S. 101) and is reached by walking about 800 feet south on an old trail from the highway. It is about 3 miles southeast of the point where the road extending up the Bogachiel River joins the Olympic Highway and is about 9 miles southeast of the town of Forks.

The map (fig. 35) shows the location of the profile of 4 holes bored in 1951 and also the location of the profile of 13 holes bored by Rigg and Richardson (1938). No borings were made in the surrounding forest, and it is possible that the peat may be more extensive than is shown on the map.

Much of this peat area is sphagnum bog, but there are two wooded areas, and on the northwestern part are the remains of an old house, a fence, and some old apple trees. There is also an old drainage ditch nearby. Evidently the property was abandoned many years ago.

The sphagnum bog has a cover of living *Sphagnum* which is growing vigorously and forming some hummocks. In addition to the usual bog flora there is an abundance of false hellebore up to 6 feet tall and also some herbaceous dogwood. These two species usually are more abundant in mountainous regions than at such low elevations as this. The coniferous trees in the wooded areas and elsewhere on the peat are mostly white pine

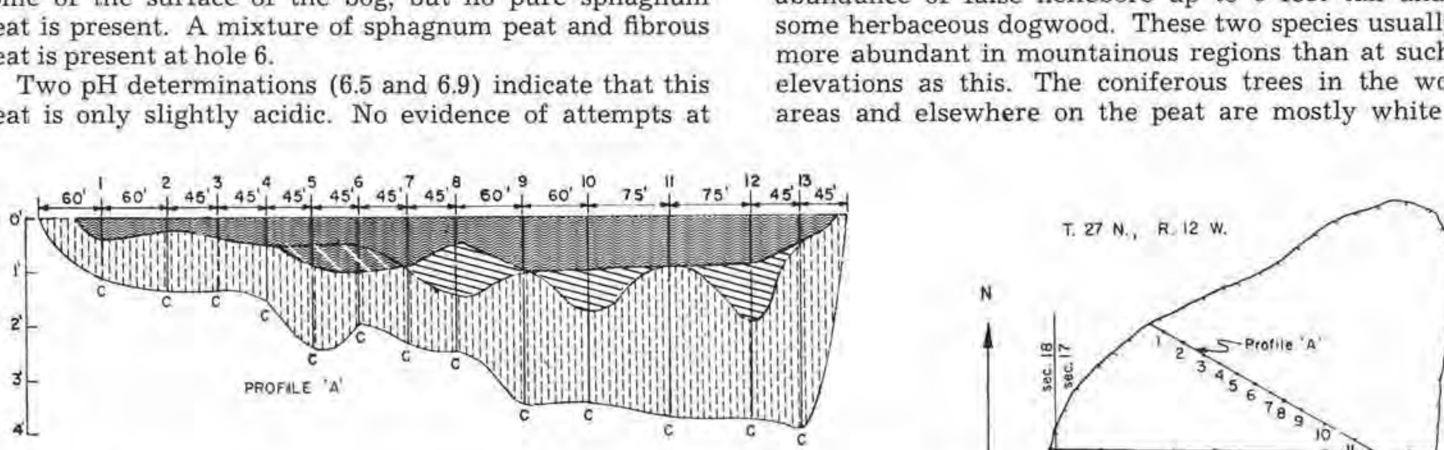


FIGURE 35.—Map and profiles of Forks peat area (18 acres). Map adapted from U. S. Corps of Engineers topographic map (Forks quadrangle) and Rigg and Richardson (1938).

and hemlock, but there is some spruce. Many of the trees of all three species are up to 16 inches in diameter, and some of the hemlocks are 24 inches. There are some spruce seedlings.

The layers of peat found in the 1951 borings are shown in profile B (fig. 35). Rigg and Richardson (1938) published a profile of the 13 holes which they bored, and this is reproduced in the present report as profile A (fig. 35). Hansen (1947) discusses forest succession in the vicinity in postglacial time as indicated by the fossil pollen which he obtained from the peat.

This peat deposit, like many others near the shore of the Pacific Ocean in Washington, is shallow. The sphagnum peat is brown and raw. The fibrous peat is dark brown to black. At the top of the layer the fibrous peat is disintegrated, and at the bottom it is completely decomposed. The muck is dark brown to black and is soft. The character of the muck and the decomposed peat vary considerably from place to place, and it is often difficult to decide in the field whether the material should be classified as muck or peat. In some places the muck merges into material which is better described as mud.

Braden Creek peat areas

A small shallow sphagnum bog (perhaps 5 acres) is situated in the SW¼ sec. 25, T. 26 N., R. 13 W., in the western part of the county close to Braden Creek. It is reached from U. S. Highway 101 by driving southeast about 1 mile on a logging road and then walking on a trail to the bog. Its elevation is considerably greater than that of the highway.

Living *Sphagnum* covers most of the surface. The peat is 1 to 4 feet deep. It is mostly fibrous peat mixed with muck. There is an old abandoned house on the peat. Other similar peat areas are in the vicinity, but there are no trails to them. These, with the one described, probably total about 50 acres.

KING COUNTY DEPOSITS

Mercer Slough peat area

The Mercer Slough peat area (535 acres) lies in secs. 4, 5, 8, 9, 16, and 17, T. 24 N., R. 5 E. U. S. Highway 10 (map, fig. 36) crosses the southern part of the area about 5 miles east of Seattle via the floating bridge across Lake Washington. The area is shown as open water and undifferentiated muck and peat by Mangum (1911), as Mukilteo peat and Rifle peat on a later soil map of King County (Poulson et al., 1952), and as marsh with some open water on the Snohomish 30-minute quadrangle (U. S. Geological Survey).

Mercer Slough is a long narrow arm of Lake Washington into which several small streams discharge. The streams have little erosive power and are carrying very little sediment. The area of exposed peat was considerably increased by drainage in 1917, when the level of Lake Washington was lowered about 7 feet by the opening of the ship canal from Lake Washington to Lake Union. The drainage from Lake Union flows through a canal and through the locks to the tidewater of Salmon Bay. The peat area slopes very gently to the south, and a sluggish stream which flows south through it to Lake Washington provides some drainage.

The vegetation on the parts of this peat area which are not in cultivation varies in different parts of the area. It comprises willows and other small trees, hardhack and other shrubs, sedges, cattails, and weeds. In 1952 a sphagnum bog with characteristic shrubs and small coniferous trees was still thriving in the western part of the area (map, fig. 36). Its area is estimated as 30 acres, and it is bordered on the south by the lateral drainage ditch between secs. 5 and 8. The bank of the ditch shows 18 inches of raw sphagnum, under which is fine brown fibrous peat.

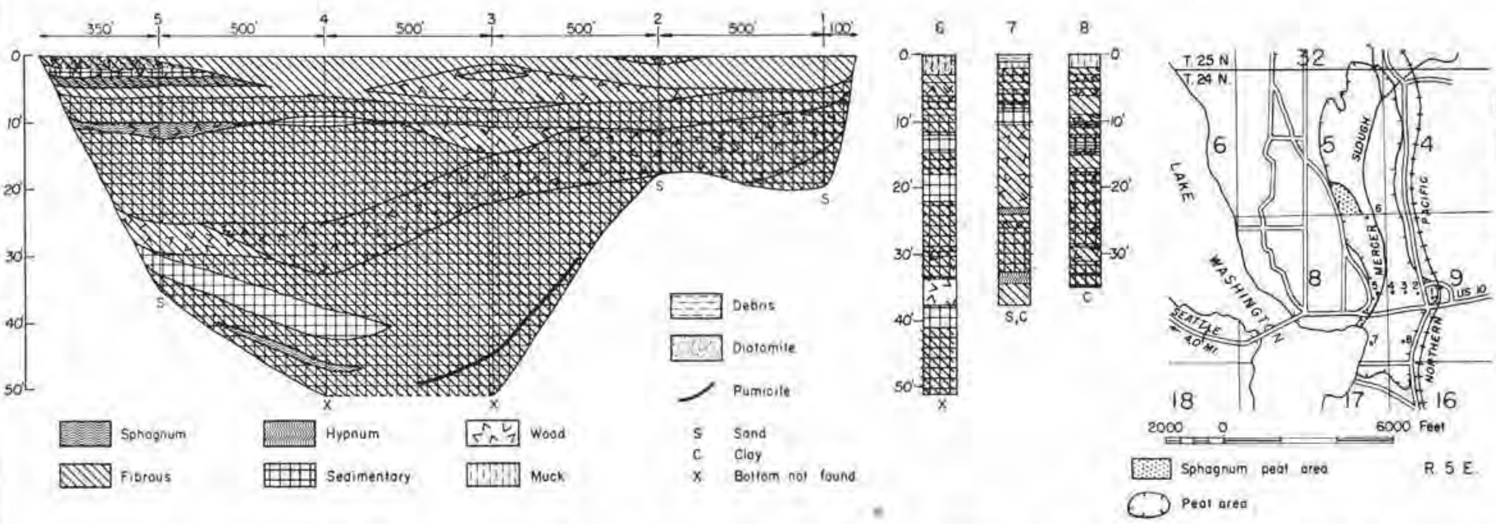


FIGURE 36.—Map, profile, and graphic logs of three holes in Mercer Slough peat area (535 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

The profile (fig. 36) starts at the east in an abandoned blueberry patch and extends westward across waste land on which willows, hardhack, evergreen blackberry vines, weeds, cattails, and swamp ferns grow. Elsewhere on the peat area there are some truck gardens and some waste land.

This is a large deep peat deposit. It is the largest one in King County, though there are 18 larger peat areas in the state. In holes 3, 4, and 6, bottom was not reached at 51 feet. The material at this depth is soft, and the only reason that deeper borings were not made was that no more rods for the peat borer were available. So far as has been determined, the peat rests on sand.

The depth of hole 6 and of the two central holes in the profile indicate a fairly extensive central deep area in this deposit, and the depths of holes 7 and 8 indicate that the deposit is somewhat shallower in its southern part near Lake Washington.

The most abundant material revealed in the profile is a mixture of fibrous peat and sedimentary peat. Woody peat is mixed with these in a layer several feet thick extending through most of the profile. A little sphagnum peat is also found, but not at the surface, and there is also some sedimentary peat. The surface layer is mostly brown fibrous peat, but this is mixed with woody peat and diatomite at the west end of the profile. The layer of white pumicite at the 45-foot depth in hole 3 is ½ inch thick. Hydrogen sulphide bubbled up from the boring in hole 1. The material in this hole changes gradually from rather strongly acidic (pH 4.7) at the 1-foot depth to weakly acidic (pH 6.5) at the 20-foot depth.

Dachnowski-Stokes (1930) bored this peat. He gives details of the kinds of peat found and mentions diatomaceous sedimentary peat. He records a layer of cream-colored volcanic ash (pumicite) 3 to 8 inches thick at the 40-foot level. Although this is a large peat area, he does not state where his borings were made.

The proximity of this peat area to a large center of population suggests its use as truck gardens and nurseries. Drainage may present difficulties, however. The character of the soil in any portion of the area that is being considered for utilization should be carefully studied. In some places the presence of diatomite may be a limiting factor in utilization.

Algona peat areas No. 1 and No. 2

These two areas of shallow peat are close together (map, fig. 37) and are conveniently described under one heading. Area No. 1 (417 acres) is in secs. 25, 26, 35, and 36, T. 21 N., R. 4 E. The town of Algona is adjacent to its northern border, and Auburn is about 3 miles north. The area is shown on the soil map of King County (Poulson et al., 1952) as Rifle peat, except an area of about 10 acres in the NE¼ sec. 35, which is shown as Greenwood peat. A number of roads cross the area, and there are occupied houses along them. It is evident from driving over these roads that the peat is very shallow. Possibly the peat may be deeper in the northeastern part of the area, as it was not examined there.

One hole was bored to a depth of 8 feet in the area

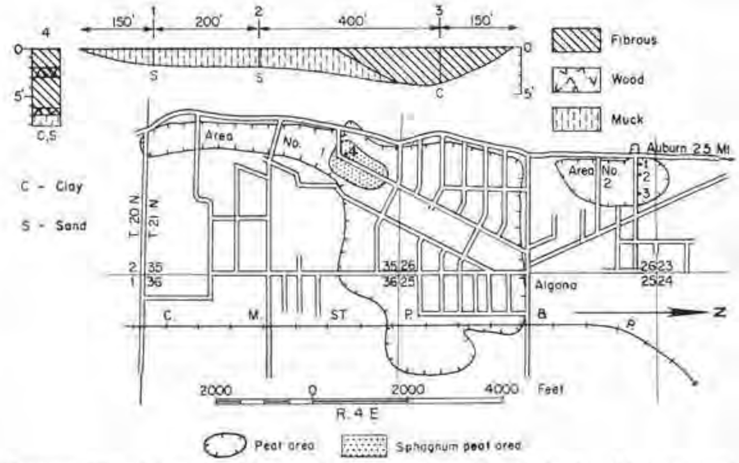


FIGURE 37.—Map, profile, and graphic log of a hole in Algona peat areas (417 acres and 45 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

mapped as Greenwood peat (map, fig. 37), where the vegetation was a dense growth of hardhack brush. The brown to dark-brown fibrous peat is dry and compact near the surface. Below the 3-foot depth it is disintegrated or decomposed. There is some wood peat mixed with it at the 2- to 3-foot depth and also at 6 to 7 feet. There are two layers of gray clay, each 1 inch thick, in the 4- to 5-foot depth and a 2-inch layer of sand at the 6-foot depth. The muck at the bottom is brown. Under the muck is 18 inches of gray clay and under this is gray sand.

Area No. 2 (45 acres) is only a few hundred feet north of No. 1. There are roads across it, and the profile of three holes is in a pasture along a road. The maximum depth of organic material is 3 feet. The muck at hole 1 is strongly acidic (pH 4.5). The fibrous peat in hole 3 is dark brown and coarse. Sand is under the muck in holes 1 and 2, and gray clay under the fibrous peat in hole 3.

Ames Lake Creek peat area

The Ames Lake Creek peat area (357 acres) lies in secs. 35 and 36, T. 26 N., R. 6 E.; secs. 1 and 12, T. 25 N., R. 6 E.; and secs. 6 and 7, T. 25 N., R. 7 E. It is about 6 miles by road south of Duvall and about 7 airline miles east of Redmond. It is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952). The topography of the region is shown on the Sultan 30-minute quadrangle and the Carnation 7½-minute quadrangle.

The peat area lies in an arm of the valley of the Snoqualmie River (map, fig. 38). Wooded land rises abruptly from the east and west sides of the peat area. Ames Lake Creek flows northward over the peat from Ames Lake to the Snoqualmie River. The land between the river and the north boundary of the peat is flat, and it is evident that this part of the valley was filled by the deposition of water-borne materials, leaving, south of the fill, the depression which was then occupied by a swamp and is now filled with peat. The creek eventually established its channel on the peat.

The channel of the creek has been artificially deepened and straightened west of the southern part of the peat area and thence northward across the peat. A lateral drainage ditch carries clear water from the east border of the peat along the line between secs. 1 and 12 to the main channel. The drainage is sufficient to remove surplus water, at least during the summer.

The profile (fig. 38) from east to west crosses a pasture, a hayfield, a small cornfield, and another pasture. There is some skunk cabbage in the wetter places in the pasture, and also there are some weeds on most of it, but the hayfield has very few weeds. The depression in which the peat lies, so far as is shown by the profile, is deep and steep sided. The most abundant material is a mixture of fibrous peat and woody peat. This ranges from brown to dark brown and from watery to compact. Most of it is decomposed. There is some clay mixed in it, and in a few places there are thin layers of clay which are not shown in the profile. The fibrous peat, where present alone, is mostly dark brown and decomposed. The muck varies from gray to brown. In hole 2 the muck at the 49-foot level was too compact to be penetrated farther with the peat borer. A layer of brown pumicite is 1 inch thick. Determinations made on material from hole 2 indicate that the peat is weakly acidic. At the 3-foot depth the pH is 5.3; at 8, 9, and 32 feet it is 6.0; and at 44 feet it is 6.5. The pH of the muck at 49 feet is 5.5. Bubbles of marsh gas arose from some of the holes during the boring.

As indicated above, there is utilization of much of this peat area for pasture . This area and the one at Miller Lake in Island County are examples of the formation of a firm surface on deep peat

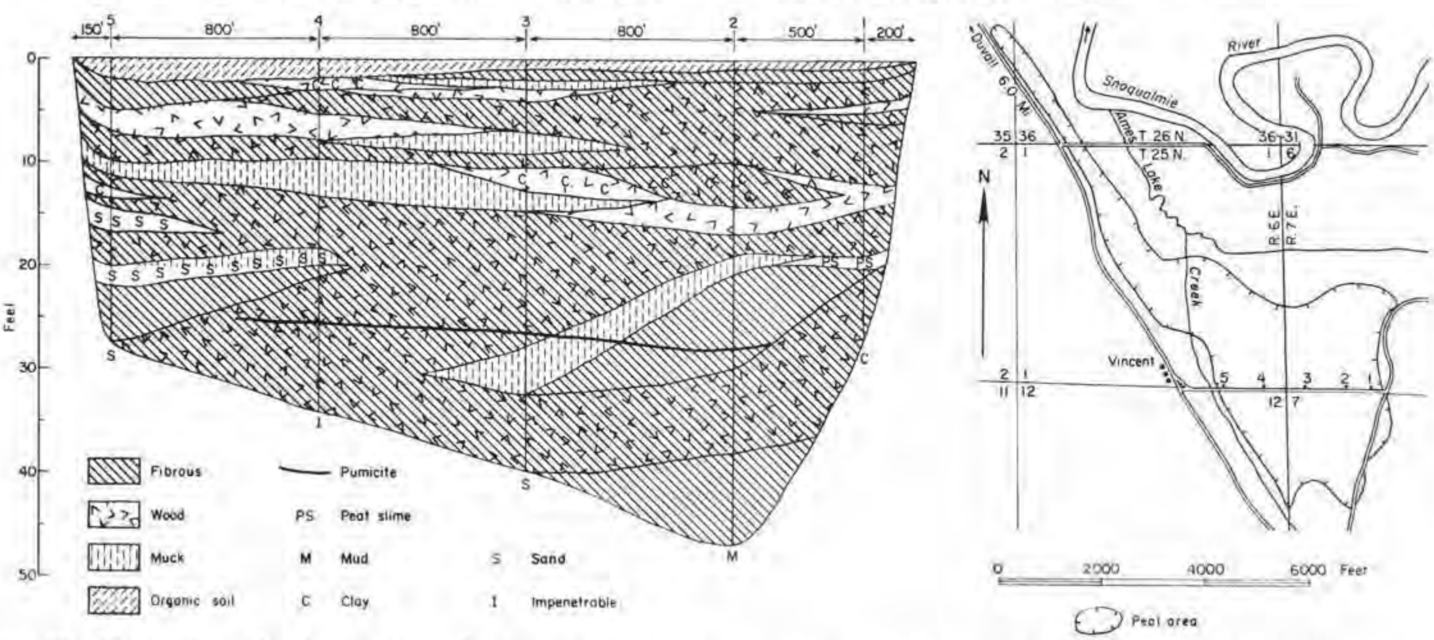


FIGURE 38.—Map and profile of Ames Lake Creek peat area (357 acres). Map adapted from U. S. Department of Agriculture soil map of King County and U. S. Army Map Service photomosaic.

Sammamish Lake peat area

The Sammamish Lake peat area (282 acres) lies in secs. 7 and 18, T. 25 N., R. 6 E., and secs. 12 and 13, T. 25 N., R. 5 E. It borders the north end of Sammamish Lake and extends about 3,000 feet along the Sammamish River, which flows from the north end of Sammamish Lake to the north end of Lake Washington (map, fig. 39). It is about 8 airline miles east of Seattle, from which it is reached by driving around the north end of Lake Washington or across it on the floating bridge. The peat is about 5 miles from Kirkland and about 1½ miles from Redmond.

The area is shown on the King County soil map (Poulson et al., 1952) mostly as Rifle peat, but some of the northern part is mapped as Mukilteo peat. Some of this peat is old lake bottom which was exposed when the level of Sammamish Lake was lowered about 7 feet in 1917. This lowering of the lake was due to the lowering of the level of Lake Washington (see Mercer Slough peat area on p. 69) and the straightening and deepening of some parts of the Sammamish River by dredging. The topography of the region is shown on the Snohomish 30-minute quadrangle.

Much of the peat area is now utilized for truck farms, but the very wet area near the lake is waste land. The part of this wet area farthest from the lake has a dense growth of small willow and dogwood trees and hardhack brush. This woody vegetation merges into a dense growth of marsh and aquatic herbs near the lake margin. Some reed canary grass has been introduced into the margin of this waste land.

The organic soil shown in the profile (fig. 39) at holes 1, 2, and 3, which were bored in a bean field, is dark brown and rather strongly acidic (pH 5.0). The fibrous peat in the upper levels is disintegrated, and in the lower levels it is decomposed. The diatomite encountered in hole 4 is light gray. The sedimentary peat at holes 5 and 6 is olive to olive brown. A 1- to 2-inch layer of pumicite is white, tan, and brown. The peat rests on gray sand.

Dachnowski-Stokes (1930) found 14 feet of peat in this area, with bluish-gray fine sand under it. He records the presence of tule-reed peat and reed-sedge peat [both fibrous], sedimentary peat, and some hypnum peat. The peat which he reports is 3½ feet deeper than that found in 1950. He does not give the location of his borings. The surface of the peat may be lower now than it was in 1930 due to shrinkage.

The yield of beans and other truck crops on this peat is good.

Phantom Lake peat area

The Phantom Lake peat area (260 acres) lies in secs. 1 and 2, T. 24 N., R. 5 E., and secs. 34 and 35, T. 25 N., R. 5 E., about 8 miles southeast of Kirkland about 2 miles east of Bellevue. It is surrounded by low hills and is close to the border between the plateau area and the westward extension of the mountain area of King County. It is irregular in shape and is a little over 2 miles long from north to south (map, fig. 40). It entirely surrounds Larsen Lake (Blueberry Lake) and extends around most of the shore of Phantom Lake. Its general elevation is 250 feet above the level of Sammamish Lake, which is about half a mile east of the southern end of the peat area, but the peat is somewhat higher between Larsen Lake and Phantom Lake. There is some drainage from Phantom Lake to Sammamish Lake. The three lakes and their elevations are shown on the Snohomish 30-minute quadrangle. The peat is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952).

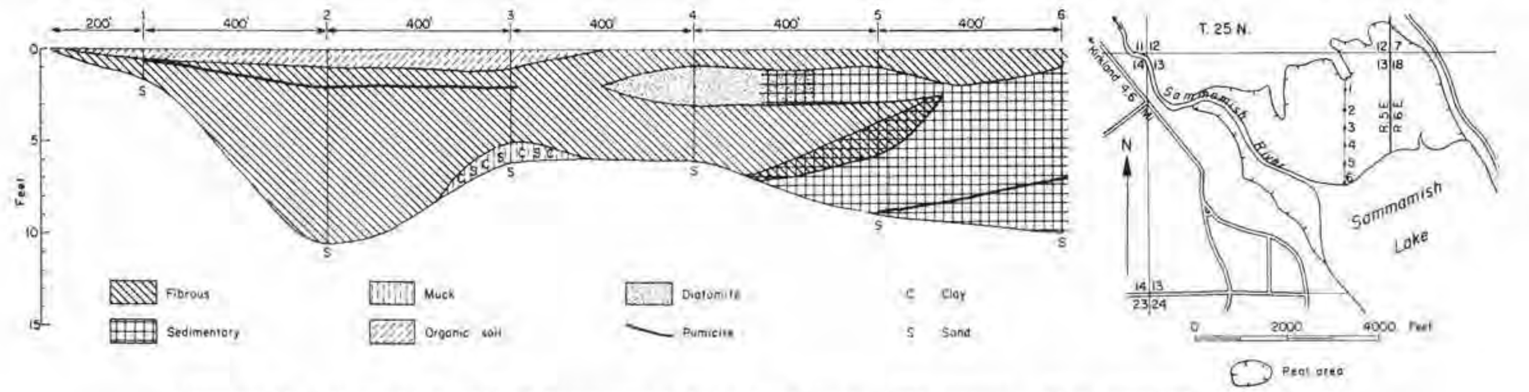


FIGURE 39.—Map and profile of Sammamish Lake peat area (282 acres). Map adapted from U. S. Department of Agriculture soil map of King county.

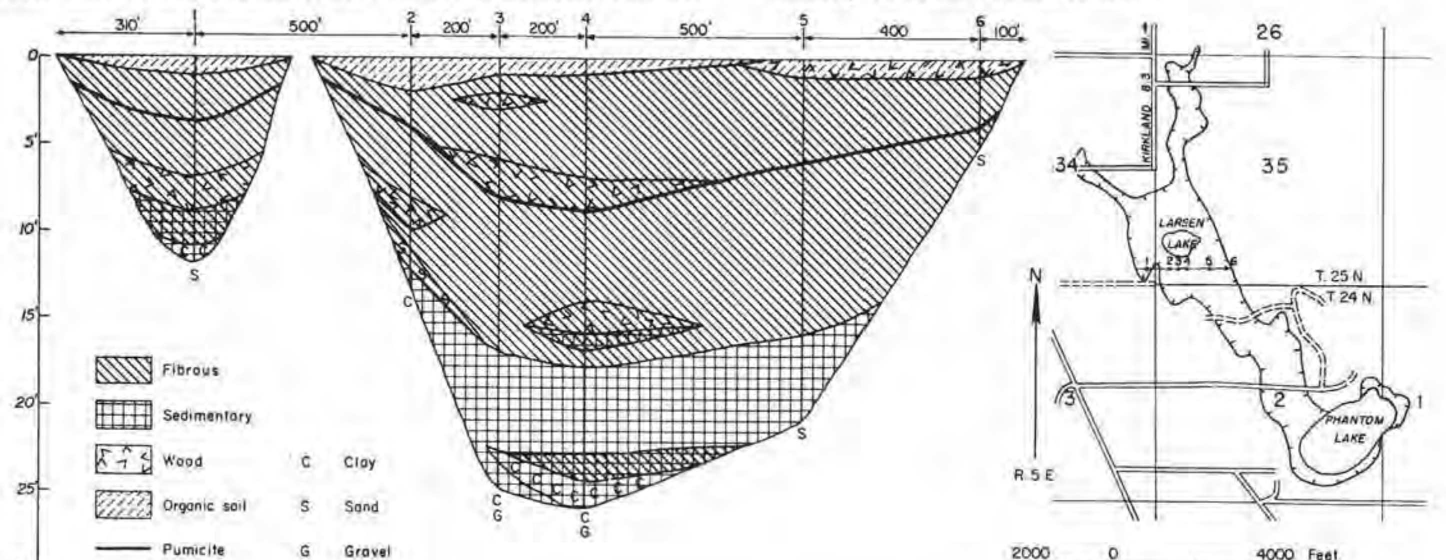


FIGURE 40.—Map and profile of Phantom Lake peat area (260 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

Much of the peat area is utilized for the production of truck crops and blueberries, but some of it is waste land partly covered with brush and partly with marsh and aquatic herbs. In the profile (fig. 40), hole 1 is in a truck farm, holes 2 to 5 are in a blueberry field, and hole 6 is in waste land covered with willows, hardhack, and weeds. The organic soil indicated in the profile is dark brown. The fibrous peat is brown to dark brown. At medium depths it is disintegrated, and at greater depths some of it is decomposed. Bubbles of hydrogen sulphide arose from hole 3. The color of the sedimentary peat is olive to olive green.

Determinations made on material from hole 3 show the usual decrease in acidity with depth. The depth, materials, and pH for these determinations are as follows: At 1 foot, peat soil, 4.2; at 2 feet, fibrous peat, 4.8; at 10 feet, fibrous peat, 5.0; and at 23 feet, sedimentary and fibrous peat, 6.5.

The layer of brown pumicite in the peat is about 1 inch thick. As in other peat of western Washington, the quantity of it is too small to be of any practical importance, but an interesting comparison of the historical significance of the pumicite in this peat with that in the Sammamish Lake peat area, which is only about 3 miles distant, may be made. As it is evident that the ash in these two areas fell at the same time, the stage of development at that date can be determined. In the Phantom Lake peat the ash is some distance from the bottom, and it is all in fibrous peat, except that at holes 3 and 4 it lies between fibrous peat and a mixture of fibrous and wood peat. At Sammamish Lake it is partly in fibrous peat near the surface and partly in sedimentary peat at depths from 7 to 9 feet, the 9-foot depth being where the peat rests on sand.

Blueberry bushes grow well on this soil and produce abundant crops of good berries. Good crops of lettuce, broccoli, cabbage, and other crops have been produced on this peat for many years.

Happy Valley-Evans Creek peat area

The Happy Valley-Evans Creek peat area (230 acres) is in secs. 16, 17, 21, and 22, T. 25 N., R. 6 E. Its western end is about 3½ miles east of Redmond, and it extends eastward about 2½ miles through the valley and along the creek (map, fig. 41). Its width varies from about 200 to about 1,700 feet. Evans Creek originates, probably from springs, near the eastern end of the area and flows into Bear Creek, which flows into the Sammamish River.

This lowland peat is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952). State Highway 2 (Redmond to Fall City) crosses the western part of it and passes on higher land just north of the eastern end. In general, the western end of the peat is rather shallow and has a fairly firm surface, but the eastern end, in sec. 22, is a morass which still contains remnants of the sphagnum bog which formerly occupied a considerable part of it. Most of the sphagnum was removed in the 1930's by the Peat Products Company by means of a scoop attached to an endless cable extending across the bog. The sphagnum was baled and marketed.

The sphagnum bog in sec. 22 was investigated by Rigg in 1928. The peat was 16 feet deep in the central part and rested on sand. Besides the sphagnum bog there were swampy areas covered with a dense growth of crab apple and brush. There were also some very watery places in which cattails and water lilies grew. Logs were being dragged across the peat by means of an endless cable operated by a donkey engine, and in the process a considerable amount of peat was also being dragged out.

Dachnowski-Stokes (1930) made borings in this peat in sec. 22. He found 13 to 15 feet of peat with coarse gray sand under it. There was a layer of sphagnum 6 feet

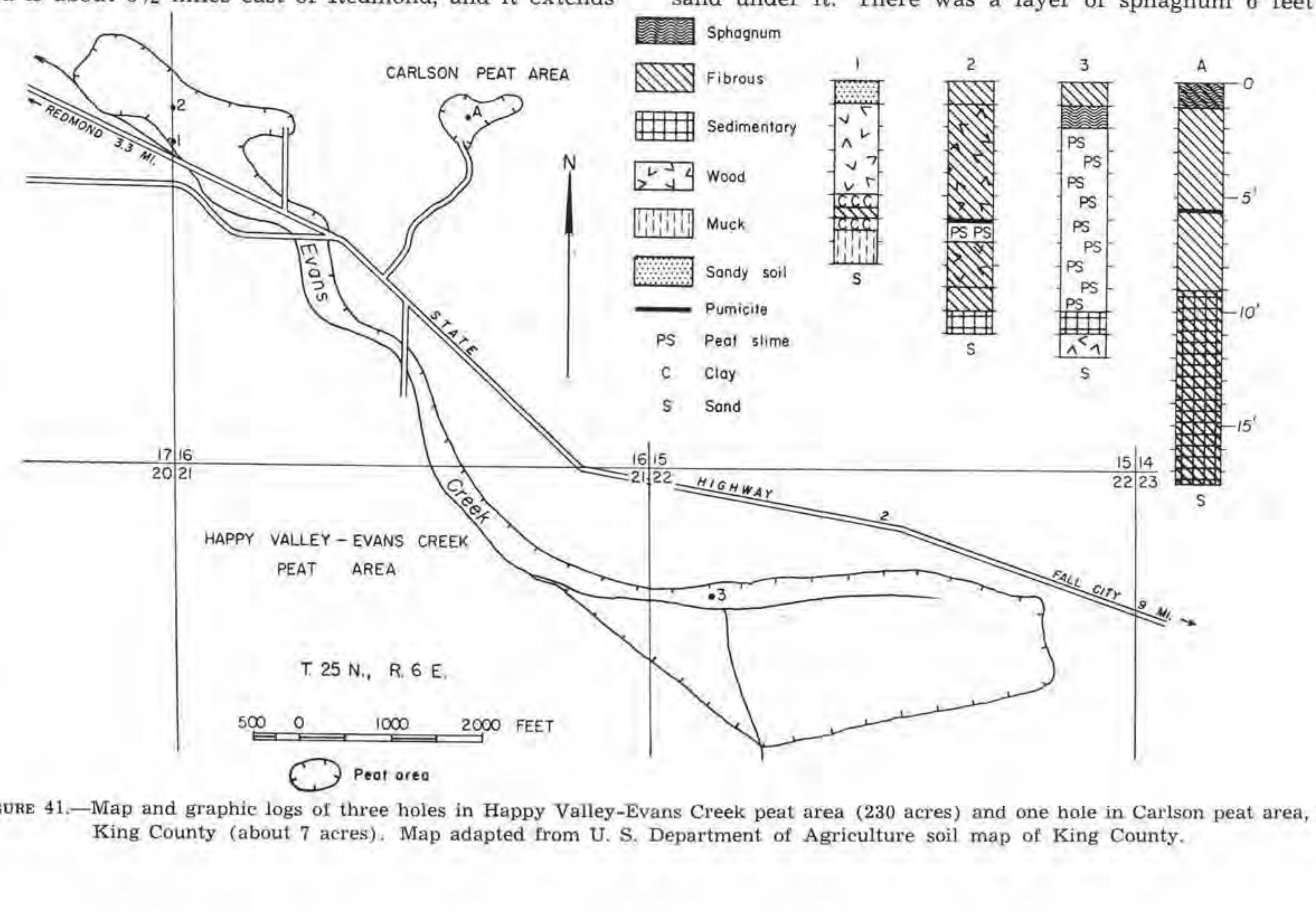


FIGURE 41.—Map and graphic logs of three holes in Happy Valley-Evans Creek peat area (230 acres) and one hole in Carlson peat area, King County (about 7 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

thick in which the water table was 18 inches below the surface. Below the sphagnum there was a layer 1 to 1½ feet thick of dark-brown peat composed of the remains of heath shrubs, coniferous trees, and sedges. Below this was a 5- to 7-foot layer of diatomaceous sedimentary peat.

Along the northern border of the peat in sec. 22 there is now some swamp vegetation and some open water. Some places that are firm enough to walk on are covered with weeds. The one boring (fig. 41) made near the border shows mostly peat slime.

The two holes bored on the line between secs. 16 and 17 (fig. 41) show much mixed wood peat and fibrous peat and some sedimentary peat, wood peat, peat slime, and clay. The presence of tan pumicite in a layer 2 inches thick in hole 2 indicates that peat formation here began a long time ago, and the presence of sedimentary peat indicates that there was standing water here. The charred material at the 9-foot depth records a fire which occurred long ago.

There are a number of farms in Happy Valley. Some of the peat area is utilized for pasturage, and some of it is in cultivation.

Renton muck and peat area

The Renton muck and peat area (180 acres) is in secs. 19 and 30, T. 23 N., R. 5 E., about 1 mile south of Renton. State Highway 5 crosses it from north to south. This lowland area, which is mostly waste land, is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952). This designation gives a correct idea of the area, though it also contains some fibrous peat.

The one hole bored to a depth of 7 feet shows mostly clay, muck, and wood; it shows only 1 foot of peat. This is a 1-foot layer of dark-brown disintegrated fibrous peat from the 3-foot to the 4-foot depth. Above the peat is 1 foot of brown muck, and the next foot above this is a mixture of acidic fibrous peat, wood peat, and clay (pH 4.8). Above this is 1 foot of gray clay. Underlying the peat to a depth of 7 feet are intermixed gray clay, wood peat, and brown muck.

Dachnowski-Stokes (1930) reports peat and silt 5 feet deep in sec. 30.

Cottage Lake peat area No. 1

The larger (85 acres) of the two Cottage Lake peat areas is in sec. 12, T. 26 N., R. 5 E., and secs. 7 and 18, T. 26 N., R. 6 E. It is reached by State Highway 2C (Woodinville to Duvall) and a county road which leads south and then west from this highway just east of the lake. This peat area lies in an irregularly shaped depression (map, fig. 42) in the plateau region. It borders the south end of the lake, and Cottage Lake Creek flows sluggishly across it and into Bear Creek, which flows into the Sammamish River. The peat is over 30 feet deep under the creek. It is shown on the soil map of King County (Poulson et al., 1952) mostly as Rifle peat, but some Mukilteo peat is shown bordering the lake.

A large part of the peat area was sphagnum bog when it was first visited by Rigg in 1928, but it has been burned several times since then, and only remnants of the bog vegetation now remain. There is still some living *Sphagnum*. Weeds have come in, and pasture grasses are established in some places. Formerly there were scattered coniferous trees on the peat area, but only a few of these have survived the fires and the ax. Willows and hardhack are abundant on the margin of the peat. The sphagnum in the vicinity of hole 6 has been removed. In 1951 a drainage ditch to Cottage Lake was dug northeastward across the southern part of the area, crossing the profile between holes 2 and 3. An older ditch provides some drainage from Cottage Lake into Cottage Lake Creek.

The sphagnum now remaining on this area (fig. 42) is mostly disintegrated, and there is too little of it to be of any economic importance. The sedge peat is dark brown and mostly disintegrated or decomposed. Hydrogen sulphide rises from it when holes are bored. The sedimentary peat is olive to brown, and much of it is extremely compact.

The peat in this area is acid, but it varies from very acidic (pH 3.7) in sphagnum at the surface to weakly

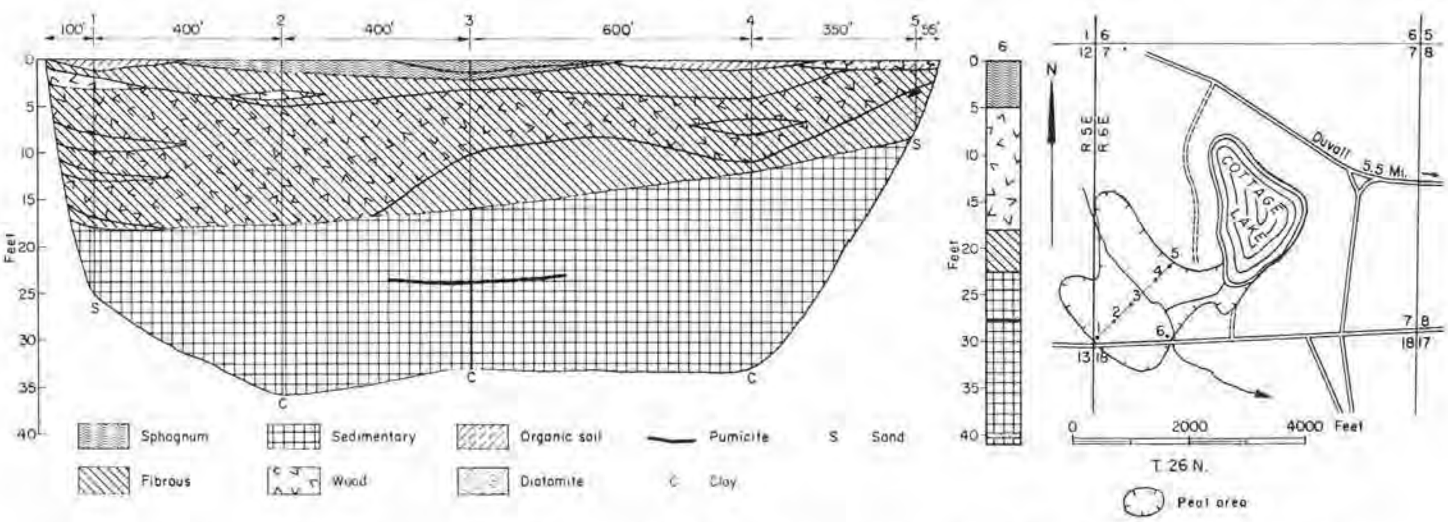


FIGURE 42.—Map, profile, and graphic log of a hole in Cottage Lake peat area No. 1 (85 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

acidic (pH 6.5) in sedimentary peat near the bottom. The pH of the organic soil at the 1-foot depth in hole 1 is 4.5. Brown and white pumicite occurs in a layer half an inch thick. There is some utilization of this peat area for pasturage, but most of it is waste land.

Cottage Lake peat area No. 2

Cottage Lake peat area No. 2 (34 acres) is in secs. 17 and 18, T. 26 N., R. 6 E. (map, fig. 43), about three quarters of a mile southeast of the south end of Cottage Lake. It is reached by driving east on the Woodinville-Duvall highway and turning south on the Redmond road at the "Y" just east of Cottage Lake. The north end of the peat is approximately 1 mile south of the "Y." The old log house on the east side of the Redmond road stands on hard land at the margin of the peat.

The area is mapped as Greenwood peat on the soil map of King County (Poulson et al., 1952). It lies in a depression in a comparatively flat region of glacial drift. The surrounding soil is mapped as Everett gravelly sandy loam except at the south, where the somewhat lower surface is shown as Lynden sandy loam.

The surface drainage of the area is sufficient to remove surplus water even in winter. Water flows slowly eastward in a natural ditch along the northern border of the peat. From the south end of the peat area water flows to Cottage Lake Creek and eventually reaches the Sammamish River. Some of this drainage at the south is channeled through ditches which have been dug recently in the peat. Farther north in the area there are some old drainage ditches overgrown with brush.

This area is a sphagnum bog mostly covered with a dense growth of bog shrubs (Labrador tea and bog laurel) 2 feet or more in height, but there are a few wet patches in which cattails and hardhack grow. A zone 20 to 100 feet or more in width around the bog is covered with hardhack brush and small trees, including cascara. A tall reed (*Phragmites communis*) occurs in the northern part of this zone. On the bog there are numerous coniferous trees, some of which are 30 feet tall, but also there are some treeless areas. The conifers are cedar, hemlock, Douglas fir, white pine, and a few small spruces. *Sphagnum* and *Hypnum* mosses and some lichens grow on the surface among the trees and shrubs.

Bottom was not reached in boring this peat (fig. 43) because with the equipment available it was not possible to bore deeper than 34 feet. The sedimentary peat at that depth is not difficult to penetrate.

The layer of sphagnum at the surface consists mainly of intact stems with leaves attached and is thus of good quality. As seen in the profile, the line of contact between it and the fibrous peat which lies under it is not sharp. The fibrous peat is brown. It varies from raw to disintegrated and contains some raw cattail peat.

The jellylike material is light yellow in color and is very soft. It contains a very few fibers. When squeezed in the hand all the material comes out between the fingers. It probably should be classified as sedimentary peat, but its yellow color and its resemblance to soft jelly merit special mention. It is not common in peat deposits in the state of Washington. A chemical analysis of a sample (no. 32, table on p. 255) shows that it is very weakly acidic (pH 6.7) and that its moisture content (90.1 percent) is not significantly different from that of some samples of fibrous and sedimentary peat from other bogs in various parts of the state. The following amounts of the constituents determined in the analysis are stated in percent of the dry weight: Ash, 59.9; chloride, 0.009; phosphorus (P_2O_5), 0.11; total nitrogen, 1.76; sulphide, 0.022. Potash (K_2O) is present, but the sample was not large enough to permit a quantitative determination.

The sedimentary peat is mostly olive green, but some of it is yellowish, and its properties vary toward those of the jellylike material.

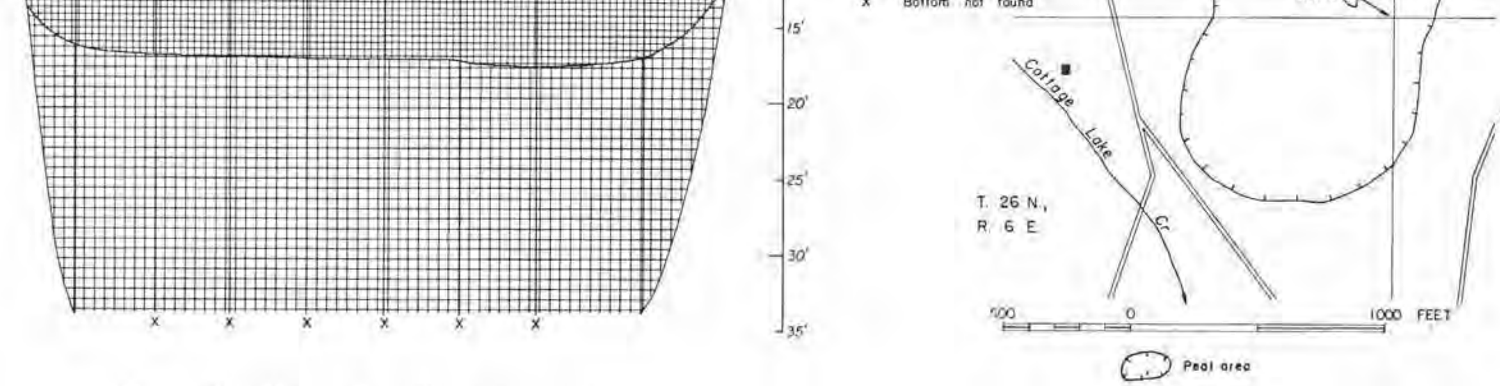


FIGURE 43.—Map and profile of Cottage Lake peat area No. 2 (34 acres). Map adapted from U. S Department of Agriculture soil map of King County.

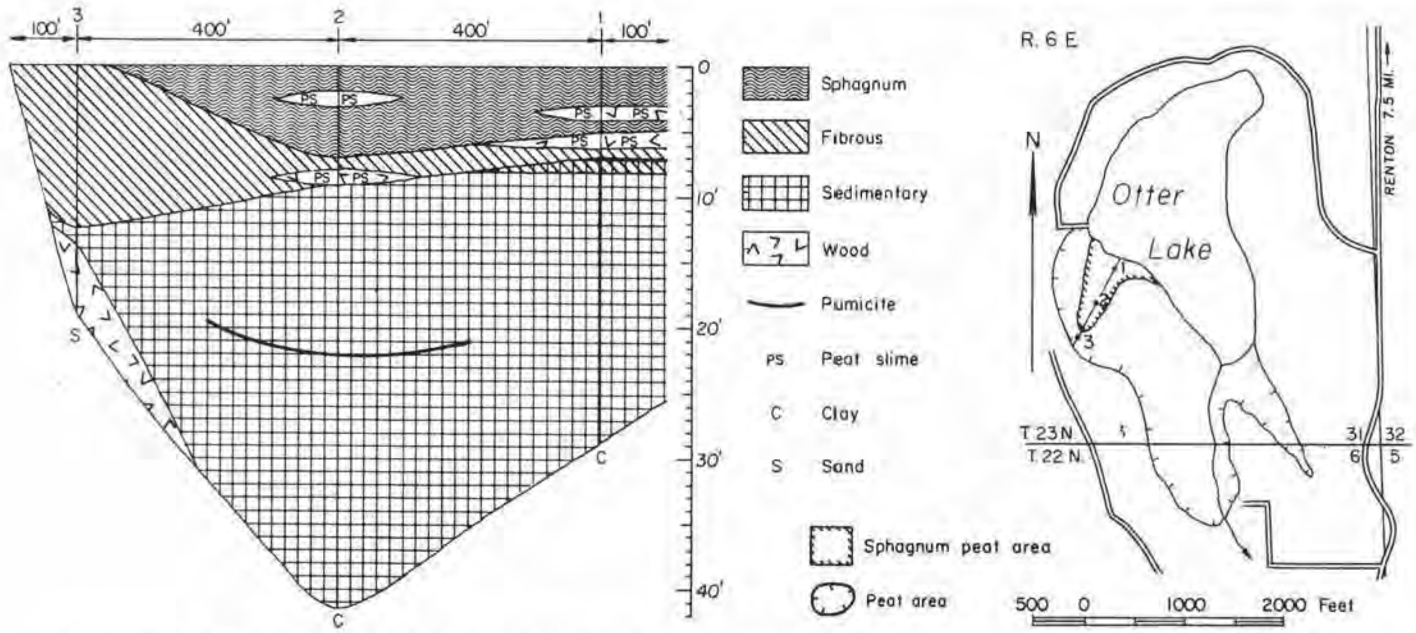


FIGURE 44.—Map and profile of Otter Lake peat area (69 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

The presence of the soft jellylike material would present difficulties in the use of mechanical equipment for removing sphagnum moss or fibrous peat from this deposit. No borings have been made in the southern part of the bog to determine whether this soft material is present there. If the water table could be lowered sufficiently, this southern part might be developed as a truck garden.

Otter Lake peat area

The Otter Lake peat area (total 69 acres, of which 6 acres is sphagnum bog) is in sec. 31, T. 23 N., R. 6 E., and sec. 6, T. 22 N., R. 6 E., about 6 miles southeast of Renton. It is reached from State Highway 5 (Renton to Enumclaw) by county roads around the north and south ends of Otter Lake. This lake is shown as Spring Lake on some maps. The peat is in the glacial drift of the plateau region and borders the south end of the lake. A small stream flows from the south end of the lake and across the peat (map, fig. 44) to Peterson Lake and thence to Cedar River. The area is mapped as Greenwood peat and Rifle peat on the soil map of King County (Poulson et al., 1952). The lake and the topography around it are shown on the Tacoma quadrangle.

Holes 1 and 2 of the profile are in a sphagnum bog, and hole 3 is in a swamp forest. The sphagnum bog has the usual herb and shrub flora, including the small creep-

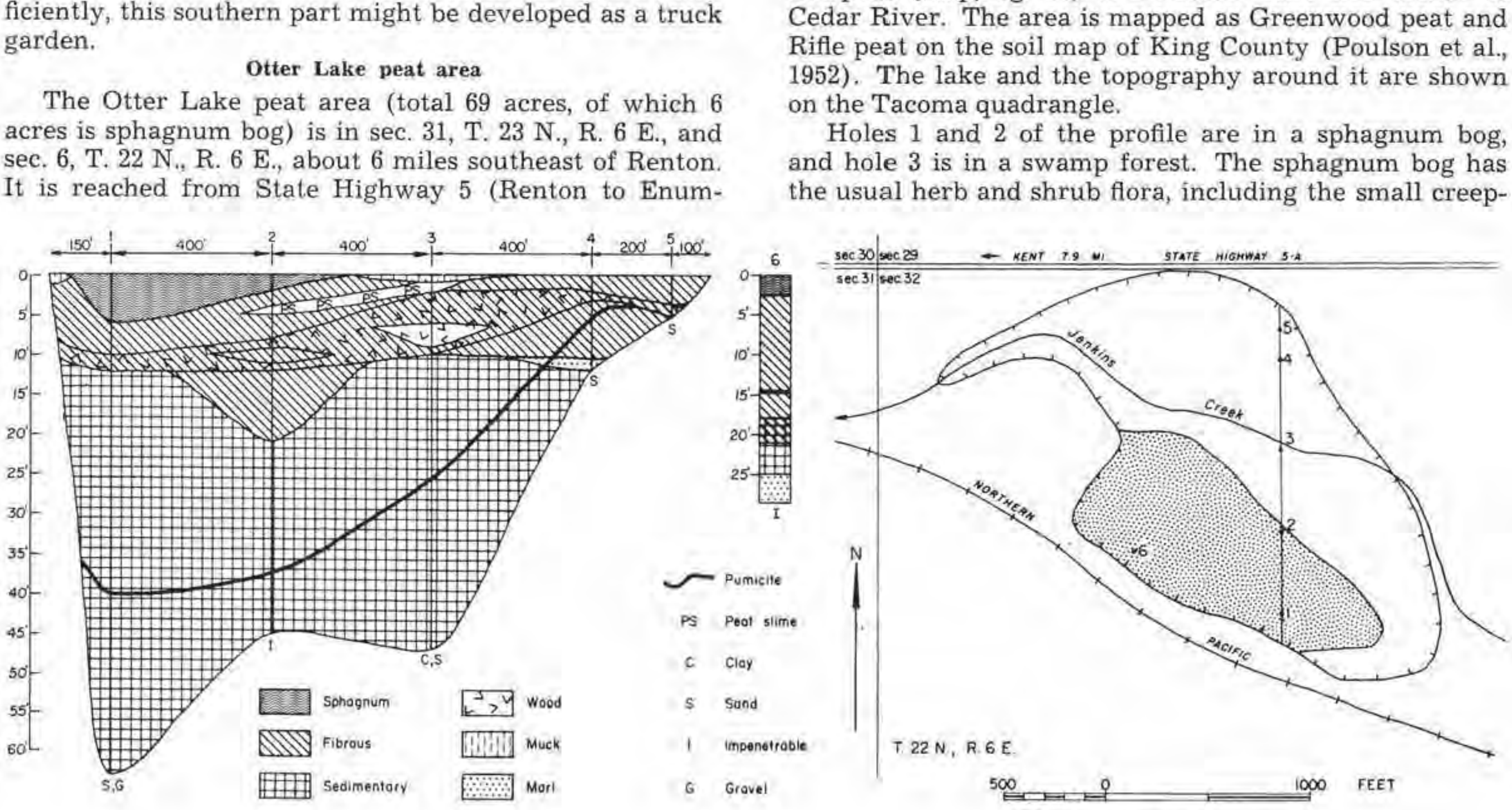


FIGURE 45.—Map, profile, and graphic log of a hole in Covington peat area (58 acres, including 20 acres of sphagnum peat). Map adapted from U. S. Department of Agriculture soil map of King County.

ing woody vines of the native cranberry. Hemlock and lodgepole pine trees (some 20 feet tall) are numerous. There are some cattails and water lilies on the border near the lake. The swamp forest consists of a dense growth of hemlock and lodgepole pine. Some of the hemlocks are 20 inches in diameter. There is some *Sphagnum* moss and also some *Hypnum* moss growing on the ground in the forest near the border of the sphagnum bog.

The sphagnum (fig. 44) is raw and is of good quality, but it is watery toward the bottom of the layer. The fibrous peat is brown and decomposed. The sedimentary peat, which forms a deep layer in comparison with the layers formed by sphagnum and fibrous peat, is soft and is olive colored. A layer of white pumicite is 1 inch thick. The clay at the bottom of holes 1 and 2 is blue. There is sand at the bottom of hole 3. Near hole 1 the water of the lake is acid (pH 4.7). No evidence of any attempt at utilization was seen.

Covington peat area

The Covington peat area (total 58 acres, of which 20 acres is sphagnum) is in sec. 32, T. 22 N., R. 6 E. (map, fig. 45). It is about 8 miles southeast of Kent and about 2 miles east of Covington station. The Northern Pacific Railway extends close along its southern border. State Highway 5A from Kent passes along part of the northern boundary of the peat. A swampy tributary to Jenkins Creek flows sluggishly westward through the peat area, and its water eventually reaches the Green River. The banks of this stream are very soft, and the peat is 47 feet deep under it. This peat area is mapped as Greenwood peat and Rifle peat on the soil map of King County (Poulson et al., 1952).

This peat lies in a deep depression (a kettle) in the glacial drift of the plateau region. This is the deepest bog (63 feet) that has been found in the state of Washington. The sphagnum bog has the usual herb and shrub vegetation and also has a good many spruce (some 40 feet tall) and hemlock trees and some Douglas fir. Other parts of the area are covered with a very wet swamp forest having conifers in some places and willows, alders, and dogwoods with hardhack and swamp herbs in others.

The sphagnum peat in the profile (fig. 45) is brown and consists mostly of whole stems with leaves still attached, though at the bottom of the layer it consists of broken stems and detached leaves. The fibrous peat is brown to dark brown, and most of it varies from disintegrated to decomposed. The sedimentary peat varies from olive to brown, and most of it is soft, but some near the bottom is extremely compact. A single hole (no. 6) bored in April 1955 shows at the 24- to 25-foot level sedimentary peat that is distinctly laminated. The laminations are very thin, and they differ slightly in color. The thick (4½-foot) layer of marl present here is unusual in King County. A layer of white pumicite is ½ to 1 inch thick.

The peat in the profile varies from rather strongly acidic near the surface to weakly acidic at deeper levels. The determinations on the material from hole 1 show: At 1 foot, sphagnum peat, pH 4.5; at 10 feet, fibrous peat, pH 6.3; at 14 feet, fibrous peat, pH 6.3; at 36 feet, sedimentary peat, pH 6.8. In hole 4 the pH of the fibrous peat at 1 foot is 4.7, and at 10 feet it is 6.2.

The sphagnum in this deposit is of good quality, and its area (20 acres) is fairly large, but to reach it from the highway on the north would require bridging the stream, which flows over deep soft peat. Possibly, entrance from the east or west might be found. For the purpose of inspection, the area can be reached by walking 2 miles east from Covington station on the railway and climbing down the bank. The fibrous peat is suitable for use on soils. Some of the northern part of the area, where most of the fibrous peat lies, was logged long ago, but the old logging roads are mostly useless now. The presence of trees on both the sphagnum and the fibrous peat must be considered in planning utilization of the material. The wetness and depth of the peat would suggest the use of a drag line.

Shadow Lake peat area

The Shadow Lake peat area (57 acres, of which 36 acres is sphagnum) is in secs. 7 and 18, T. 22 N., R. 6 E.,

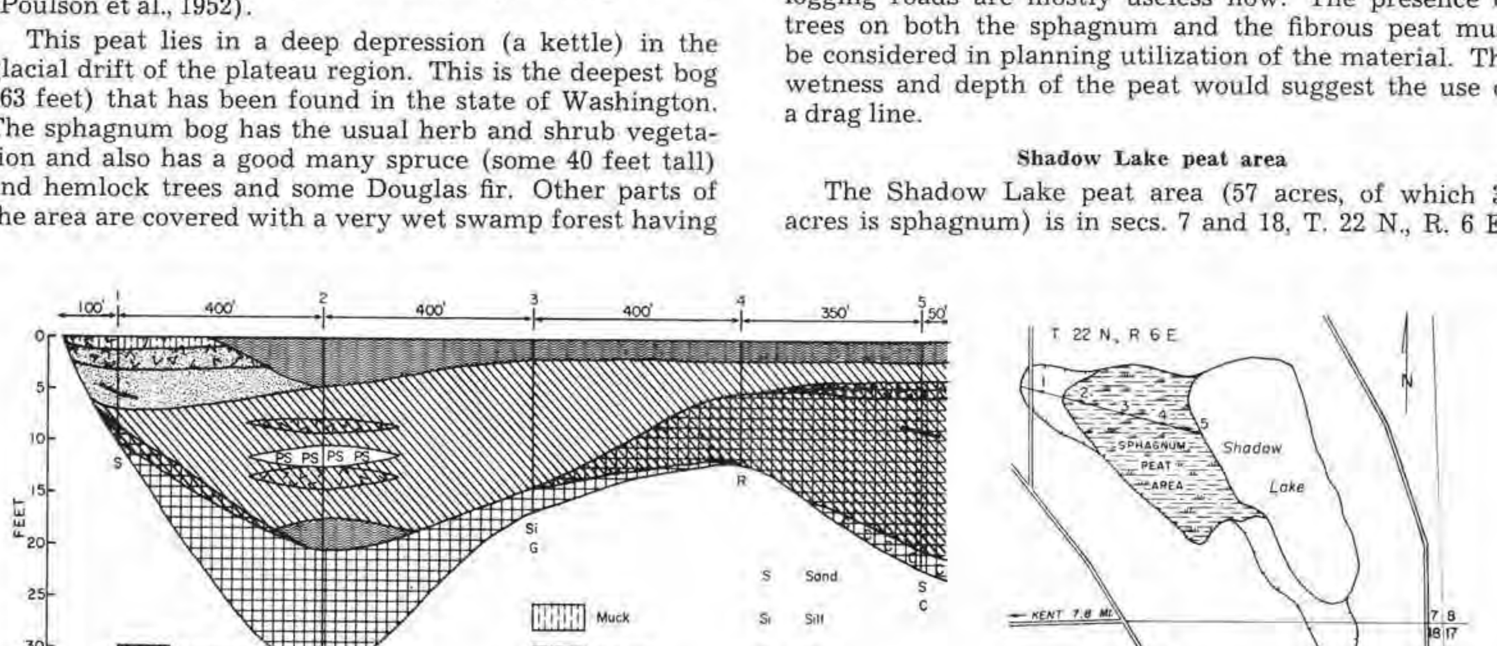


FIGURE 46.—Map and profile of Shadow Lake Peat area (57 acres, including 36 acres of sphagnum peat). Map adapted from U. S. Department of Agriculture soil map of King County.

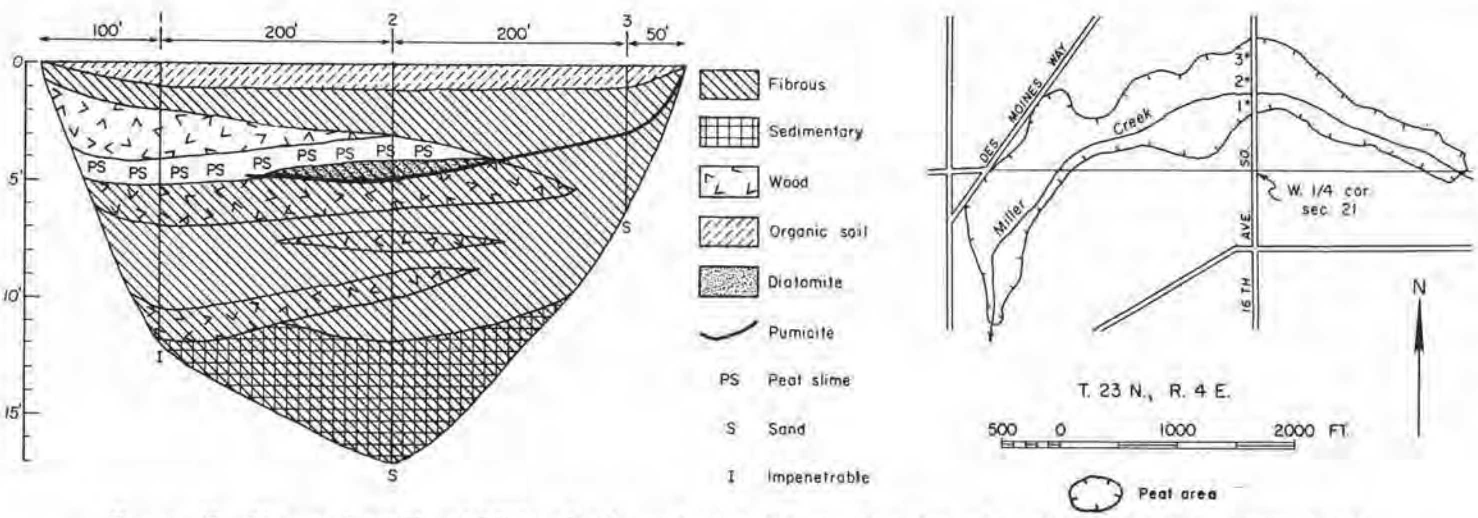


FIGURE 47.—Map and profile of Miller Creek peat area (56 acres). Map adapted from U. S. Deparment of Agriculture soil map of King County.

bordering the west side of Shadow Lake (map, fig. 46). It is about 8 miles east of Kent. A county road crosses the western part of it. The area is mapped as Greenwood peat and Rifle peat on the soil map of King County (Poulson et al., 1952). The peat and the lake which it borders lie in a depression in the glacial drift of the plateau region. The lake is known as Shadow Lake but is shown as Spoon Lake on some maps.

More than half of this peat area is sphagnum bog, in which the usual bog herbs and low shrubs are found. Scattered spruce and hemlock trees also occur. *Hypnum* moss is more abundant in this sphagnum bog than in most sphagnum bogs of western Washington. In many places living *Hypnum* is more abundant than living *Sphagnum*. The western part of this peat area is swamp forest in which cedar, alder, and dogwood trees grow. Water celery and other semiaquatic plants grow among the trees. The south arm of this area was not examined.

The acreage of sphagnum peat (fig. 46) is large, but the peat is shallow. The quality of the sphagnum is good, but it is somewhat mixed with hypnum, which lacks the high water-absorbing power of sphagnum. The sedge pest varies from disintegrated to decomposed. The diatomite found in hole 1 is light brown and contains some wood. A layer of tan and brown pumicite is half an inch thick. No evidence of any attempt at utilization was seen.

Miller Creek peat area

The Miller Creek peat area (56 acres) is in secs. 20 and 21, T. 23 N., R. 4 E. (map, fig. 47). It is about 2 miles south of the south city limits of Seattle, and the streets and avenues in the vicinity are numbered on the Seattle system. Sixteenth Avenue South crosses the peat from north to south, and Southwest 146th Street extends near the southern border.

This peat is in the plateau region and extends about 1 mile along Miller Creek, which flows southwestward into Puget Sound. Its maximum width is about 800 feet. It is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952). A few blocks west of the profile, fibrous peat is being excavated and sold in small transparent plastic bags by Hi-Line Leaf Mold Products, 15012 Des Moines Way, Seattle. In the vicinity of the profile the peat is utilized for truck gardens.

The profile is parallel to a drainage ditch which extends to the creek. The peat soil at the surface is black. The fibrous peat is dark brown to black, is disintegrated to decomposed, and contains some diatomite. At hole 1 the peat at the 12-foot depth is so compact that bottom could not be reached with the peat borer The sedimentary peat is olive in color and rests on sand. The layer of brown pumicite is ½ inch thick. Tests made at hole 1 indicate that this peat is rather weakly acidic and that the acidity at the 12-foot depth is only slightly less than at the surface. The pH at 1 foot is 5.0; at 8 feet, 5.3; and at 12 feet, also 5.3.

Aries Farm peat area

The Aries Farm peat area is in sec. 34, T. 26 N., R. 5 E., about 2 miles northwest of Redmond, from which it is reached by a county road. It is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952). The outline of the peat area as shown on this map indicates 54 acres, but it is evidently larger than shown, as hole 1 of the profile (map, fig. 48) is not within the peat area as shown on the soil map. The exact boundaries of the peat have not been determined.

This peat area lies in the flat valley through which the Sammamish River flows on its course from Sammamish Lake to Lake Washington. The channel of the river in the vicinity of the peat is shown as a canal on Metsker's Map of King County. The channel was dredged after the level of Lake Washington was lowered about 7 feet in 1917. (See Mercer Slough peat area on p. 69). This, of course, increased the drainage from the peat area and probably laid bare some parts that were formerly under water. The entire flat in which the peat lies is shown as marsh with a meandering stream flowing through it on the Snohomish 30-minute quadrangle, the topography for which was surveyed in 1893-94-95.

The relative positions of the 1-inch layer of brown pumicite in the peat here and the pumicite in the Sam-

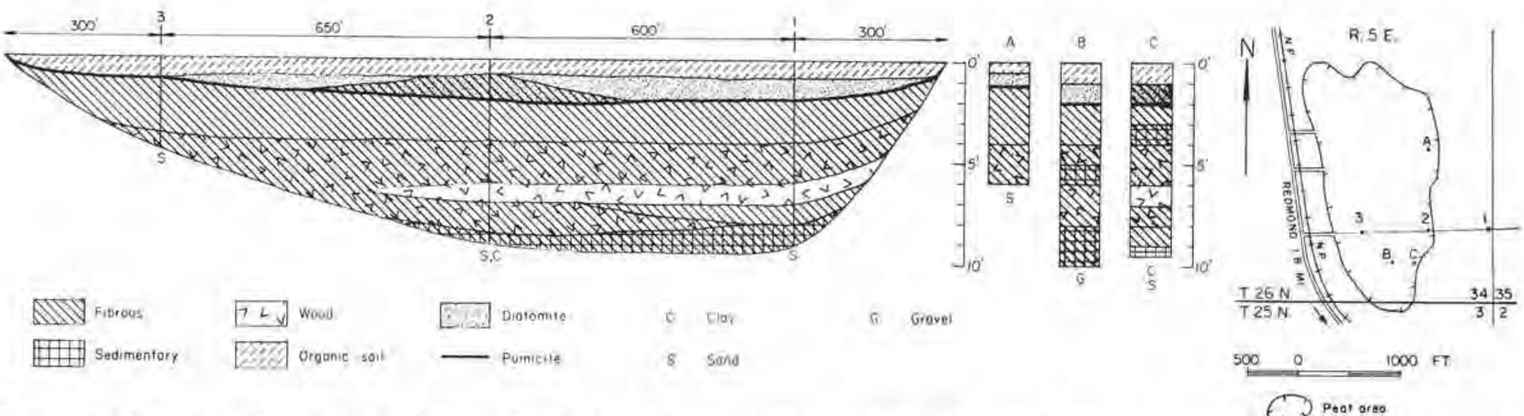


FIGURE 48.—Map, profile, and graphic logs of three holes in Aries Farm peat area (54 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

mamish Lake peat area (fig. 39), which is in the same flat, indicate the comparative stage of development at the time of the ash fall. The presence of a layer of diatomite in all holes in the Aries peat indicates standing water. Its brown color indicates mixture with organic matter. The fibrous peat is light brown to brown and is disintegrated to decomposed. The peat rests on sand, gravel, and clay.

The organic soil at the surface is strongly acidic (pH 4.4 to 4.6). Most of the peat area is now utilized as a truck farm, but some of it is in pasture. All borings shown on the map (fig. 48) are on the truck farm. Hole 1 is close to a drainage ditch, and there is pasture land on the east side of the ditch.

Dolloff Lake peat area

The Dolloff Lake peat area (52 acres) is in secs. 3, 9, and 10, T. 21 N., R. 4 E., about 3 miles northwest of Auburn, from which it is reached by paved roads and improved roads The lake and the peat lie in a depression in the glacial drift of the plateau region. The peat entirely surrounds the lake, and most of it is shown as Rifle peat and Mukilteo peat on the soil map of King County (Poulson et al., 1952). A small area is shown as Greenwood peat. Mills Creek, which has been deepened to increase drainage, flows from the south end of the lake (map, fig. 49) to Green River. The lake and the topography around it are shown on the Tacoma quadrangle.

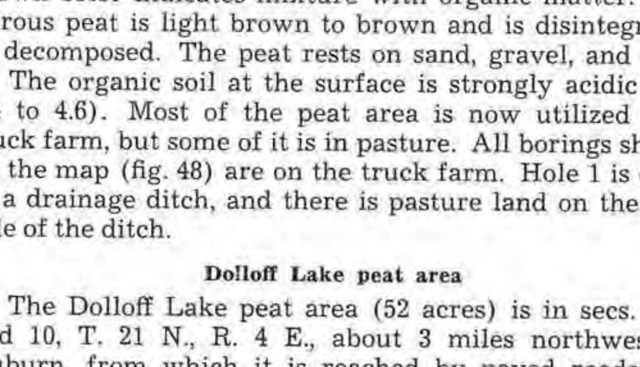


FIGURE 49.—Map and graphic log of a hole in Dolloff Lake peat area (52 acres). Map adapted from U. S. Department of Agriculture soil map of King County and U. S. Army Map Service photomosaic.

This peat was investigated only at the south end, where peat is being removed and sold in bulk by R. S. Hord, Rt. 3, Box R-56, Auburn. One hole was bored near the south end of the lake. The mixture of muck and diatomite at the surface (fig. 49) is brown. The fibrous peat is brown and varies from disintegrated to decomposed. The sedimentary peat is olive in color and is mixed with fibrous peat. It has 2 inches of mixed sand and clay at the bottom. Under this is gravel. The total depth of the peat in this hole is 11 feet.

Beaver Lake peat area

The Beaver Lake peat area (48 acres) is in secs. 3 and 10, T. 24 N., R. 6 E., about 4 airline miles northeast of Issaquah, from which it is reached by paved roads and improved roads. It does not border the lake. Its eastern border is about a mile west of the lake. It lies at an elevation of 550 feet above sea level, in a depression in the glacial drift of the plateau region just north of the westward extension of the mountain region. This peat is mapped as Mukilteo peat on the soil map of King County (Poulson et al., 1952). A county road (map, fig. 50) crosses the peat from east to west on a trestle.

The profile (fig. 50) is parallel to a drainage ditch. The vegetation at hole 1 consists of sedges, hardhack, bracken fern, and evergreen blackberry. Hole 2 is in a small sphagnum bog which has the usual bog herbs and shrubs with some small scattered cedar and hemlock trees.

The sphagnum at hole 2 is brown and is of good quality except that near the bottom of the layer it is very watery and is mixed with twigs. The fibrous peat, which is found mostly at hole 1, varies from light brown to brown and from raw to disintegrated. The sedimentary peat, which is 38 feet deep at hole 2, varies from olive to olive brown and dark brown. The thickness of the deposit of this material indicates that there was standing water here for a very long time. The 1- to 1½-inch layer of white pumicite serves to correlate the several stages of the development of this peat area with the stages of development of other peat areas in King County and adjoining counties. For instance, in the Redmond peat area the deposition of sedimentary peat had ceased at the time of the fall of the pumicite, and fibrous peat was being formed; while in

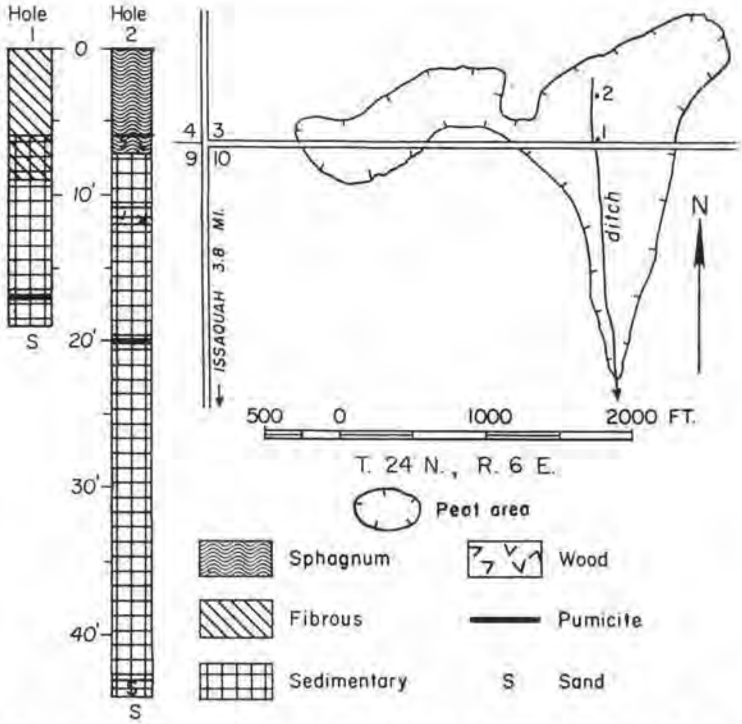


FIGURE 50.—Map and graphic logs of two holes in Beaver Lake peat area (48 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

the Beaver Lake peat area the deposition of sedimentary peat continued for a long time after the fall of pumicite.

Some of this peat area is utilized for pasture, but much of it is waste land. Sphagnum for local use could be obtained here, but the quantity is too small for commercial development.

Ravenna peat area

The Ravenna peat area, which is in Seattle, is very irregular in shape (map, fig. 51). Its extreme southern border is approximately at East 74th Street and its northern limit is East 82d Street. Its western border is a short distance east of Ravenna Avenue and its extreme eastern border is 30th Avenue N.E. It lies in a depression in glacial drift. This peat originally was 45 acres in area. A tract of 14.78 acres extending from East 76th Street to East 80th Street and from 25th Avenue N.E. to 28th Avenue N.E. belongs to the Seattle Park Department and has been improved for use as a playfield. This includes some hard land in addition to nearly one-third of the original peat area. During 1954 the peat was removed by the use of a power shovel and a dragline, and the excavation was filled with dirt. Some boulders up to 3 feet long were found on the sand at the bottom. In making the excavation water was encountered and pumping was necessary. There were some small houses on the Park Department property and some others on the peat east of this property. The part of the peat area north of East 80th Street has been in use as a truck garden for about 20 years.

The five holes bored in this peat area show mostly fibrous peat. At various depths in some holes this is mixed with woody peat, and at holes 1 and 3 it is mixed with sedimentary peat at the bottom (fig. 51). The fibrous peat varies from brown to dark brown, and from raw at the surface to disintegrated and decomposed at deeper levels. The organic soil and the muck are black. The layer of brown pumicite is 1 to 2 inches thick.

Difficulty was found a few years ago in getting support for a sewer across this peat, and concrete had to be used. Apparently there have been some difficulties in getting firm foundations for houses on this peat. Commercial fertilizer is added every year to the truck garden, and the crops are good.

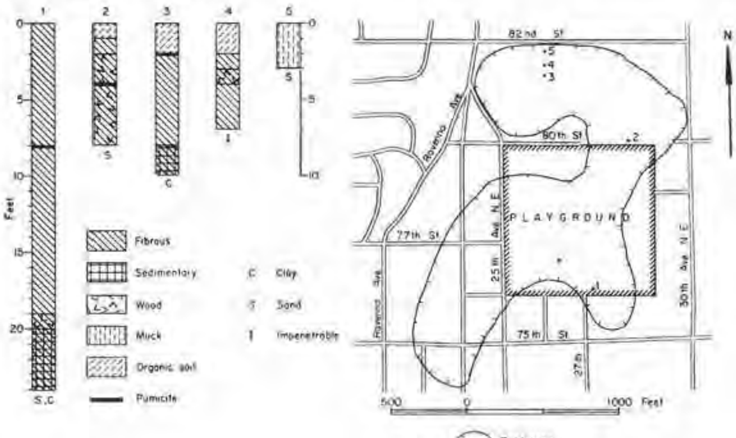


FIGURE 51.—Map and graphic logs of five holes in Ravenna peat area (45 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

Steel Lake peat areas No. 1 and No. 2

The Steel Lake peat areas (No. 1 is 19 acres; No. 2 is 25 acres) are in sec. 4, T. 21 N., R. 4 E. They lie on opposite sides of a county road (map, fig. 52), about 4 miles northwest of Auburn. U. S. Highway 99 passes about 800 feet west of area No. 2 at a point 17.3 miles south of Seattle and 11.4 miles north of Tacoma. Both areas lie in depressions in the glacial drift of the plateau area. On the soil map of King County (Poulson et al., 1952) area No. 1 is mapped as Greenwood peat, and area No. 2 is also mapped as Greenwood peat except the northern part, which is mapped as Mukilteo peat.

Both areas have been ditched, but no water was flowing in the ditches in July 1951. Area No. 1 is partly a truck garden, partly pasture, and partly waste land. Area No. 2 is covered with a dense growth of hardhack with some Labrador tea, *Sphagnum* moss, small living deciduous trees, and some small dead hemlocks. The presence of an old ditch and an old fence now overgrown with hardhack indicates earlier attempts at utilization.

The peat in these two areas (fig. 52) is practically all fibrous. It is brown to dark brown. Much of it is decomposed, and hydrogen sulphide bubbled up from some of the holes while the borings were being made. Tests made in area No. 2 show that the peat is rather strongly acidic (pH 3.7 to 4.3). Brown pumicite is found in both areas in a layer 1 inch to 2 inches thick. A comparison of the position of the pumicite in these two areas with its position in the Lakota peat area, which is about 3 miles

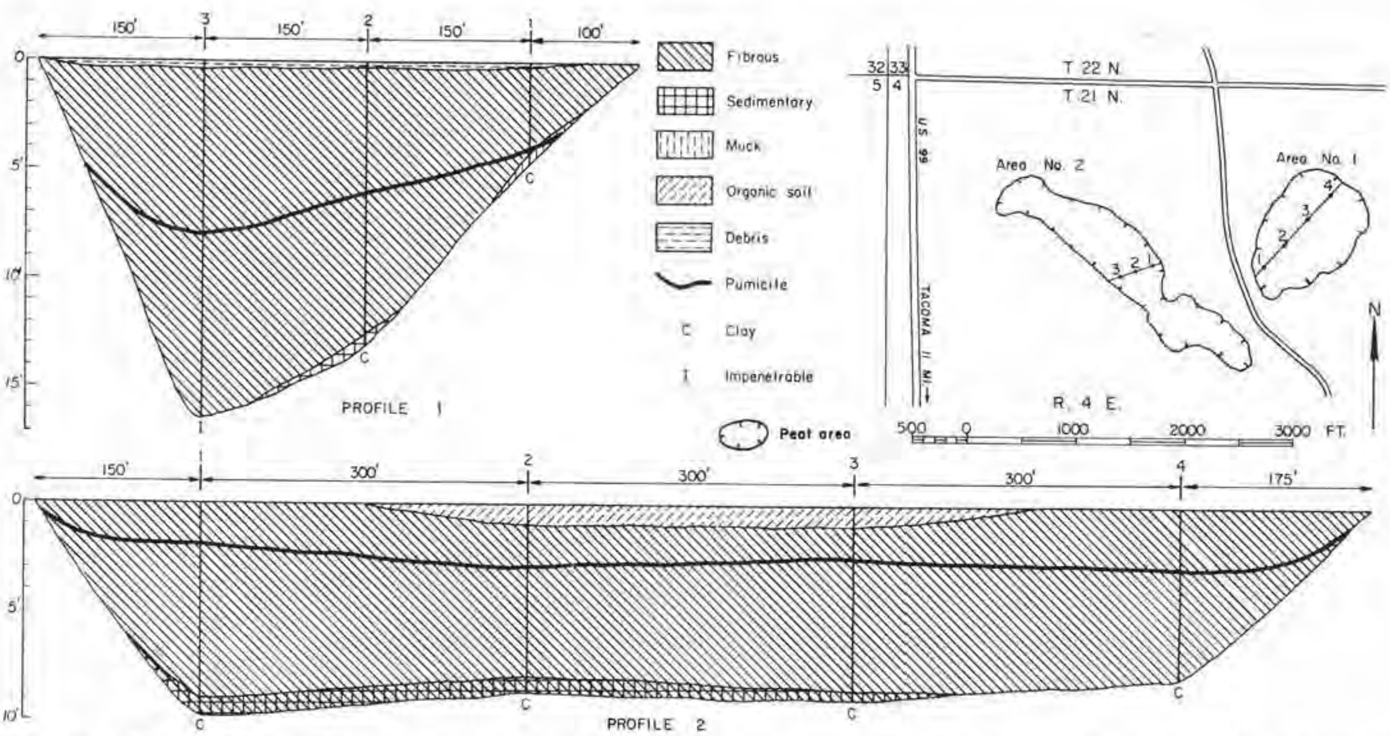


FIGURE 52.—Map and profiles of Steel Lake peat areas (19 and 25 acres). Map adapted from U. S. Department of Agriculture soil map of King County and U. S. Army Map Service photomosaics.

west of them, indicates that when the fall of pumicite occurred the three deposits were in somewhat the same stage of development.

Moss Lake peat area

The Moss Lake peat area (42 acres, of which 32 acres is sphagnum) is in sec. 36, T. 26 N., R. 7 E., about 6 airline miles southeast of Duvall. It is reached from State Highway 15B (Duvall to Fall City) by turning up the hill at Stillwater. It is a little over 3 miles by the county road from Stillwater to Moss Lake.

The peat area (map, fig. 53) surrounds the lake. A stream flows southeastward from the lake across the sphagnum to the Tolt River. The peat and the lake lie in a depression in the glacial drift near the eastern border of the plateau region, close to the mountains. On the soil map of King County (Poulson et al., 1952) this area is mapped as Greenwood peat, except the northern part, which is mapped as Rifle peat.

The sphagnum bog is very wet, and living *Sphagnum* is abundant on it. It has the typical vegetation of bog herbs and shrubs, including the small creeping woody vines of the native cranberry. The sphagnum at the east end of the lake (fig. 53) near the outlet is 8 feet deep and is of good quality but is watery. It is strongly acidic (pH 4.5). Below the sphagnum layer there is a 3-foot layer of mixed sphagnum and fibrous peat which varies from disintegrated to decomposed The color of the 22½ feet of sedimentary peat varies from light olive brown to brown. There is some char 12 to 13 feet below the surface of this peat deposit, which may have resulted from a fire on the bog or may have been washed in from the surrounding slopes The layer of white pumicite at the 26½-foot depth is ½ inch thick. The peat rests on blue clay.

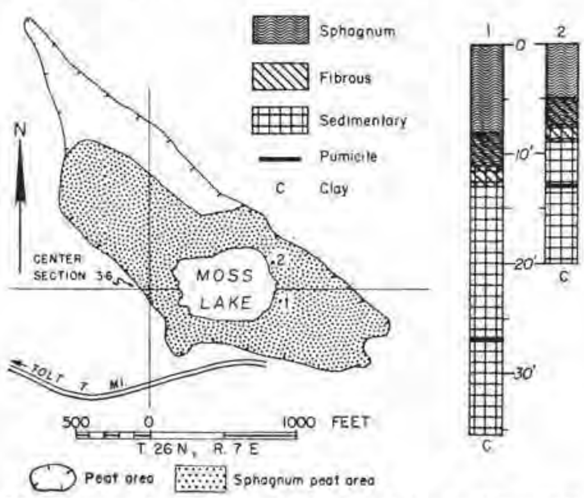


FIGURE 53.—Map and graphic logs of two holes in Moss Lake peat area (42 acres, including 32 acres of sphagnum). Map adapted from U. S. Department of Agriculture soil map of King County.

A moss drying plant was constructed at the east end of the lake in about 1920, but it burned. Some work was done in 1953 and 1954 preparatory to utilizing the moss peat in this deposit.

This lake with the peat area and the surrounding slopes would be an excellent place for the establishment of a game refuge for the conservation of wild life.

Bow Lake peat area

The Bow Lake peat area (36 acres) is in sec. 33, T. 22 N., R. 4 E. Its western border is about 400 feet east of U. S. Highway 99, about 10 miles south of Seattle and 19

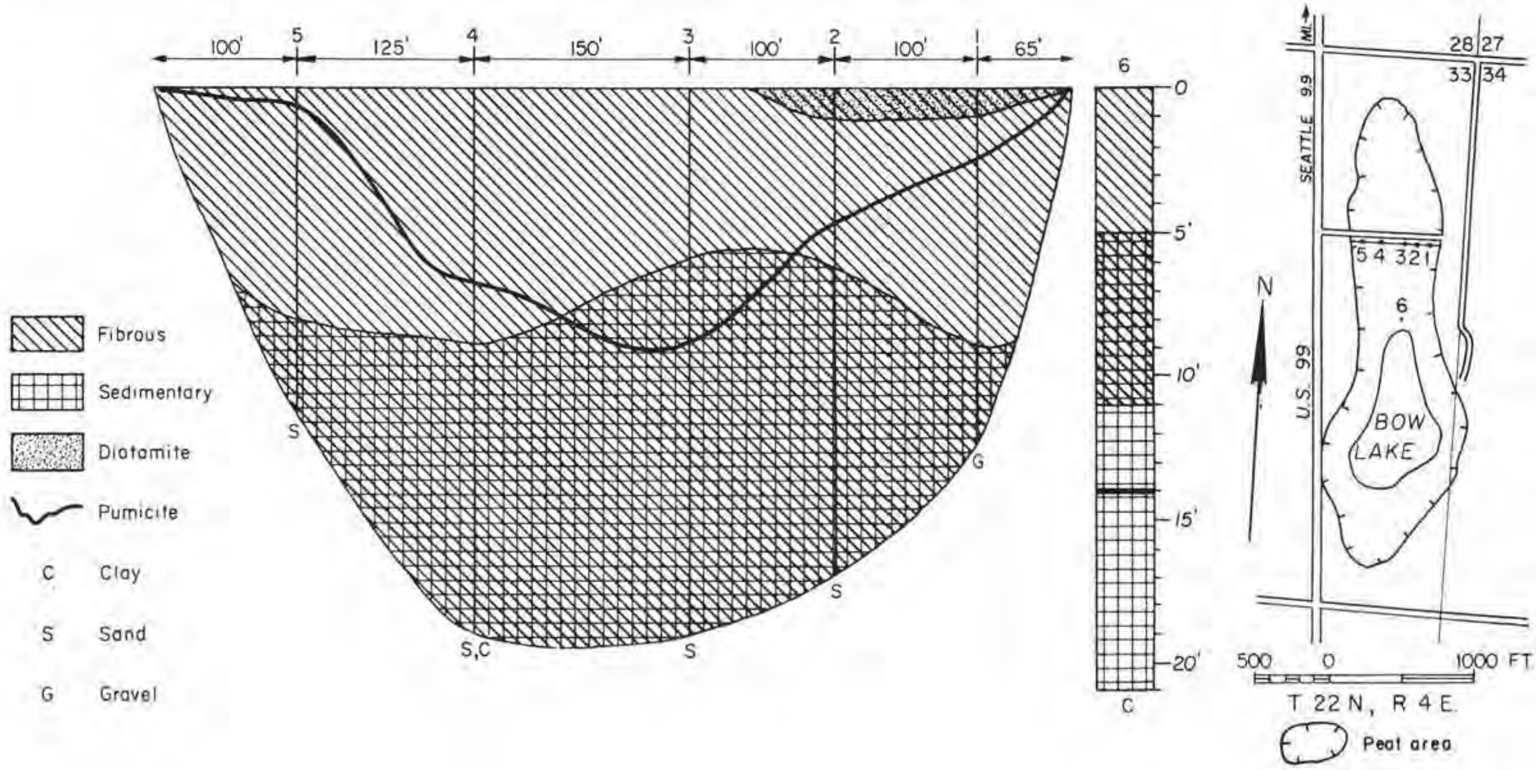


FIGURE 54.—Map, profile, and graphic log of a hole in Bow Lake peat area (36 acres). Map adapted from U. S. Department of Agriculture soil map of King County and U. S. Army Map Service photomosaic.

miles from Tacoma. It is just across the highway from the Seattle-Tacoma Airport. The lake and the peat lie in a depression in the glacial drift of the plateau region. It is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952).

In 1951 peat was being removed from this deposit and sold in bulk by three different operators. These were: Bow Lake Humus Company, 18118 Pacific Highway South, Seattle; Bow Lake Farms, 3540 South 188th Street, Seattle; and Mrs. C. A. Gessner, Route 4, Box 3201, Seattle. In 1958 only the Bow Lake Humus Company was still operating. The removal by the use of a power shovel and a drag line has been going on for several years. A road (map, fig. 54) has been constructed across the area by dumping dirt on the peat, and the profile is parallel to this road and about 50 feet south of it. The pond just north of this road occupies an excavation made by the removal of peat.

The vegetation now remaining on this peat area is composed mostly of sedges, grasses, and hardhack, though there is some aquatic vegetation near the lake. The sewage-disposal plant for the Seattle-Tacoma Airport is on the southwest shore of the lake.

The fibrous peat is brown to dark brown and varies from disintegrated to decomposed. The color of the sedimentary peat is olive. It rests on sand, gravel, and clay. The layer of brown and white pumicite is ½ to 1 inch thick.

Tests at various depths down to 15 feet on the peat in the profile indicate that its acidity is on the borderline between strongly acidic and weakly acidic (pH 4.5 to 5.2).

FIGURE 55.—Excavating peat with clamshell shovel, Bow Lake Humus Company.

Lake Twelve peat area

The Lake Twelve peat area (estimated at 35 acres) is in secs. 7 and 8, T. 21 N., R. 7 E., about 20 miles southeast of Renton, from which it is reached by State Highway 5 and a county road. It is about 2 miles northeast of Black Diamond. It borders the east end of Lake Twelve and extends eastward for about a mile as a narrow strip, through which a stream flows into the lake. The lake and

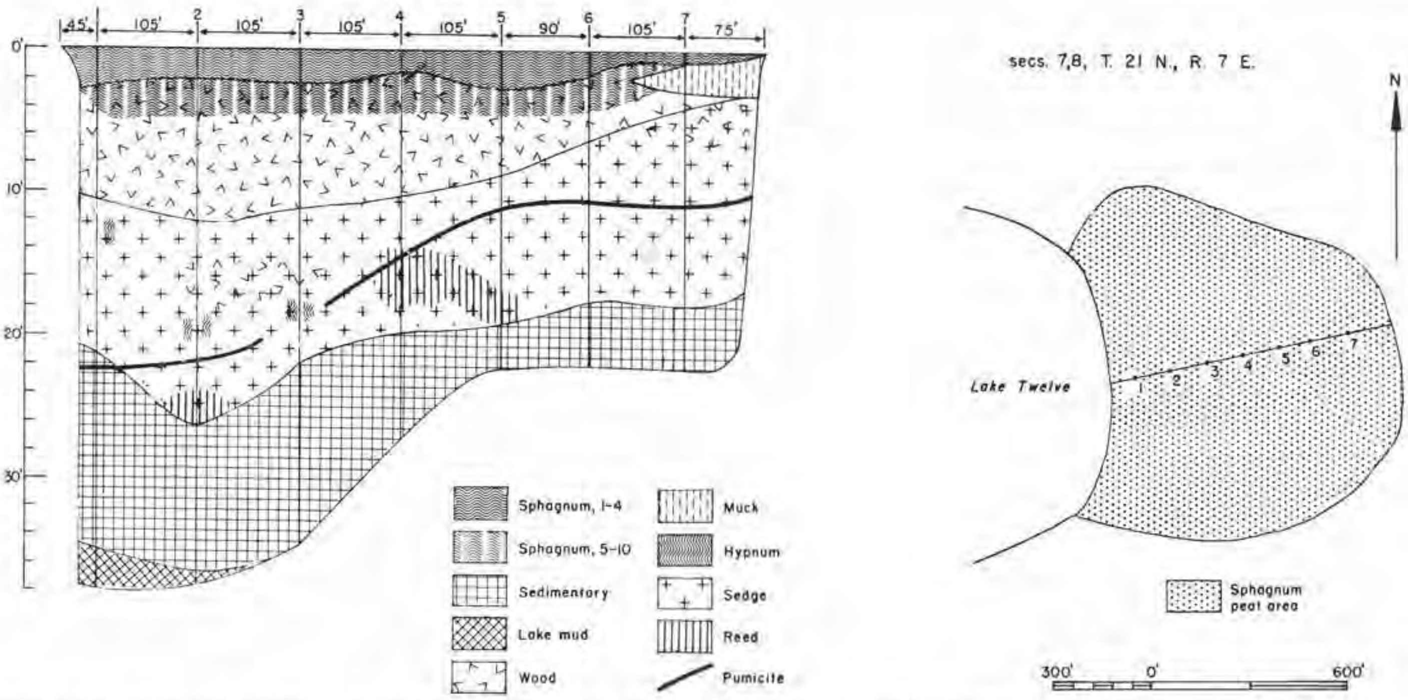


FIGURE 56.—Map and profile of Lake Twelve peat area (35 acres, estimated). Map adapted from Rigg and Richardson (1938).

the peat are in a depression in the glacial drift of the plateau region.

The part of the peat area which borders the east end of the lake is a sphagnum bog (about 7 acres); this merges gradually into the swamp forest which covers much of the eastern part of the peat area. The whole area is mapped as Rifle peat on the soil map of King County (Poulson et al., 1952).

The sketch map and profile (fig. 56) are redrawn from Rigg and Richardson (1938). They cover the sphagnum bog only. At the time of the field study on which the sketch map and profile are based the bog was covered with the usual low bog shrubs, including native cranberry vines. Among these *Sphagnum* moss grew abundantly, and *Hypnum* moss formed hummocks. There were also some swamp plants, including skunk cabbage. Cedar trees varying in height from 2 to 30 feet were abundant, and there were also some hemlocks and a few small Douglas firs.

Dachnowski-Stokes (1930) has also recorded data of the peat in this sphagnum bog.

Cedar Mountain peat area

The Cedar Mountain peat area (33 acres) is in sec. 30, T. 23 N., R. 6 E., about 1 mile west of the village of Cedar Mountain. It is 5½ miles southeast of Renton, from which it is reached by State Highway 5 and a logging road, the end of which is shown on the map (fig. 57). The peat lies in a depression in the glacial drift of the plateau region. It is mapped as Greenwood peat on the soil map of King County (Poulson et al., 1952).

This peat area is a sphagnum bog with a fringe of hardhack swamp around the margin. The bog is covered with low shrubs (Labrador tea and bog laurel among which *Sphagnum* and native cranberry vines grow. Also growing on the bog are small scattered coniferous trees, which consist mostly of hemlock with a few spruce and fir.

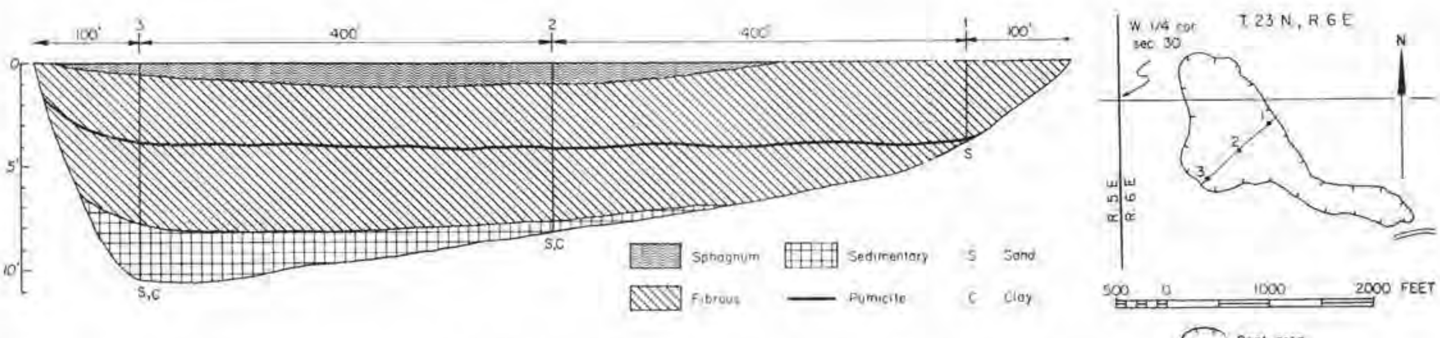


FIGURE 57.—Map and profile of Cedar Mountain peat area (33 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

Most of the peat in the profile (fig. 57) is fibrous. It is brown to dark brown and varies from disintegrated to decomposed. The sphagnum is in a rather thin layer but is of good quality. The sedimentary peat is olive in color. The layer of brown pumicite is 1 inch thick at hole 1, and 2 inches thick at hole 3.

No evidence of any attempt at utilization of this peat was seen. Utilization would require improving the logging road and extending it onto the peat.

Panther Lake peat area

The Panther Lake peat area (32 acres) is in secs. 4 and 5, T. 22 N., R. 5 E., about 4 miles south of Renton and 4 miles north of Kent. A county road (map, fig. 58) crosses the southern tip of the peat, and other roads extend near it. The lake and the peat, which entirely surrounds it, lie in a depression in the glacial drift of the plateau region. The area is mapped as Greenwood, Mukilteo, and Rifle peat on the soil map of King County (Poulson et al., 1952).

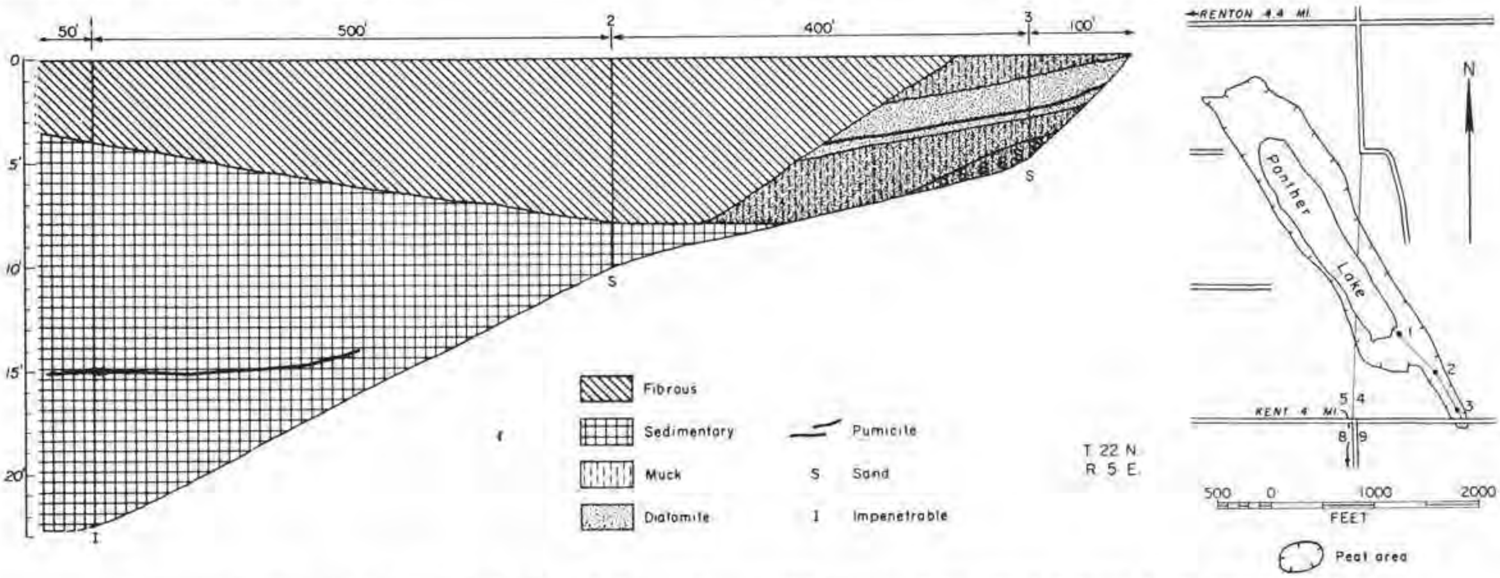


FIGURE 58.—Map and profile of Panther Lake peat area (32 acres). Map adapted from U. S. Department of Agriculture soil map of King County.

The fibrous peat (fig. 58) is brown to dark brown, and some of it is disintegrated. Near the surface at hole 1 it is strongly acidic (pH 4.3). Bubbles of hydrogen sulphide arose from this hole. The sedimentary peat is olive brown and compact. At hole 1 it is too compact to be penetrated with the peat borer beyond the 22½-foot depth. The diatomite is light to light brown and is mostly dry in summer. The mixture of diatomite and muck is dark brown. The pumicite is white in hole 1 and brown in hole 3. It is in a layer ¾ to 1 inch thick.

South of the lake part of the peat area is utilized as a pasture and part as a hayfield, and part near the lake is swampy waste land. The northern part of the area was not investigated.

Lakota peat area

The Lakota peat area (27 acres) is in sec. 12, T. 21 N., R. 3 E., and sec. 7, T. 21 N., R. 4 E. (map, fig. 59), about 6 miles northeast of Tacoma, about 5 miles west of Auburn, and about 1 mile southeast of Lakota. It lies in an undrained depression in the glacial drift of the plateau region about 1 mile from salt water and about 250 feet above sea level. The area is mapped as Mukilteo peat on the soil map of King County (Poulson et al., 1952).

This peat area is mostly a sedge meadow with some hardhack brush, numerous tussocks of rushes, and some grasses. Near the south border there is a dense growth of willows and hardhack, under which are numerous trunks of old fallen trees.

The fibrous peat (fig. 59) is brown to dark brown and varies from disintegrated to decomposed. The mixture of fibrous and sedimentary peat is olive brown. The mixture of woody peat and fibrous peat in hole 4 is dark brown and decomposed and is compact at the bottom. The layer of brown pumicite is ½ inch to 2 inches thick. The peat rests on gray clay and greenish-gray sand.

This peat is strongly acidic. At hole 2 the pH is as follows: At 3 feet, fibrous, 4.0; at 10 feet, fibrous, 4.8; at 18 feet, fibrous and sedimentary, 4.5.

Some of the peat area is used for pasture.

Sunnydale peat area

The Sunnydale peat area (26 acres) is in secs. 16 and 17, T. 23 N., R. 4 E., about 3 miles south of the city limits of Seattle and just east of the highway which leads from Seattle to Des Moines. It lies in a depression in the gravelly glacial drift of the plateau region and includes a pond (Tub Lake or Bug Lake). There is some drainage from the south end of the peat area to Miller Creek, which flows to Puget Sound. Many houses are on the hard land surrounding this peat, but the peat itself has not been changed much by man's activities, which have consisted mainly in building wire fences across it, apparently to mark property lines, and putting in a small float for fishing. The peat is mapped as Greenwood peat on the soil map of King County (Poulson et al., 1952).

A sphagnum bog surrounds the pond and constitutes the larger part of the area. Between the sphagnum bog and

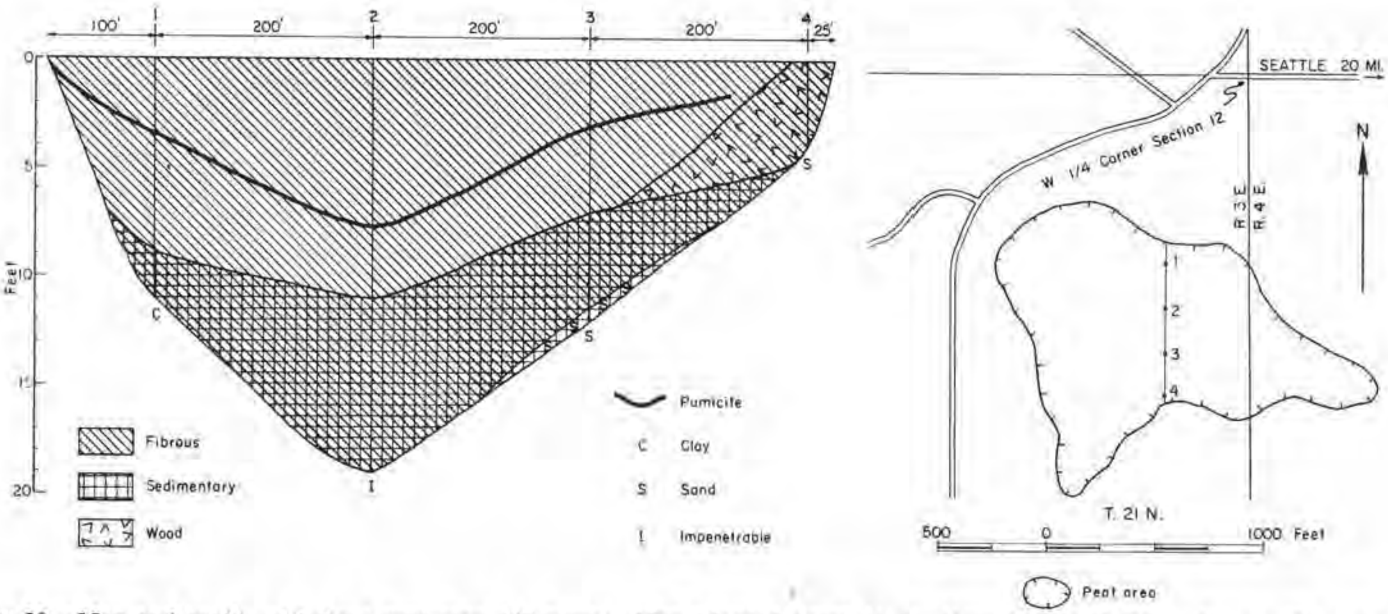


FIGURE 59.—Map and profile of Lakota peat area (27 acres). Map adapted from U. S. Department of Agriculture soil map of King County and U. S. Army Map Service photomosaic.

the glacial drift is a zone 100 feet or more in width which is occupied mostly by coniferous forest, but in some places by brush and small deciduous trees, and in a few places by sedges.

A more detailed examination of the sphagnum bog and its relation to the pond and to the zone of forest, brush, and sedge shows how the peat deposit has developed, and the boring of two profiles confirms the conclusions thus reached. The relationships shown here form an excellent example of bog development, something found in many bogs but seldom so well delineated. Four stages of plant succession are present, each forming a zone around the pond:

(1) Growing in the margin of the pond is aquatic vegetation, the remains of which are slowly filling the pond. Water lilies, purple marshlocks, and small submerged aquatic plants are the principal species in this zone.

(2) A zone 50 feet or less in width borders the zone of aquatic plants. This is a mat which floats on the water but is attached to the older bog which adjoins it. It is a sphagnum bog which is in the herb stage of development but is already being invaded by some bog shrubs which are still small. The principal herbaceous species here are sedges, cattails, and sundew. Some native cranberry vines and some small Labrador tea and bog laurel shrubs are present here.

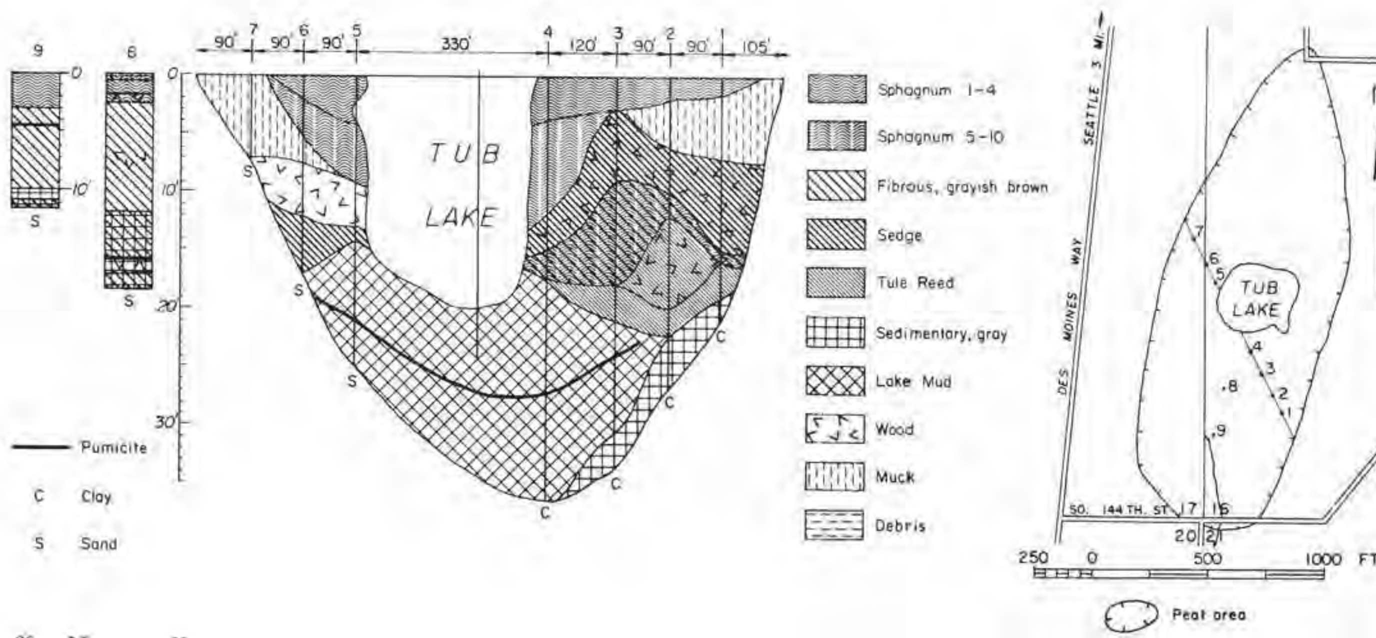


FIGURE 60.—Map, profile, and graphic logs of two holes in Sunnydale peat area (26 acres). Map adapted from U. S. Department of Agriculture soil map of King County, U. S. Army Map Service photomosiac, and Rigg and Richardson (1938).

(3) An older sphagnum bog occupies the larger part of the peat area and is in the shrub stage of development. The principal shrubs are Labrador tea and bog laurel, forming a dense shrubby growth, in which there are some bracken ferns. There are some old hemlock stumps and some young hemlock trees mostly less than 1 foot tall.

(4) An outer zone, 100 feet or more wide, extends to the hard land. In this zone, particularly at the south side of the area, the vegetation is mostly hemlocks, some of which are 1 foot in diameter, though there are also some cedars and a few Douglas firs. In places this is an open forest with no undergrowth, but in other places there is a rather dense undergrowth of shrubs and some herbaceous species. The fact that there is peat 11 feet deep (fig. 60) under this forest indicates that this is a natural forest succession on a bog.

These four stages in the natural plant succession from the open water of the pond to the hemlock forest are not separated from each other by sharp boundaries but show gradual transitions. That this succession is slow as measured in terms of human life is indicated by the fact that changes have not been very pronounced since Rigg first visited and recorded a description of this bog in 1921.

A sketch map and a profile of this bog were published by Rigg and Richardson (1938). A new map (fig. 60) has been prepared on the basis of more complete information, and two additional holes have been bored. The location of the old profile and the two new holes are shown on this map. The old profile and the new profile of two holes are shown in figure 60. In hole 8 of the new profile, the upper 1 foot of sphagnum is of good quality (raw and brown). The 1 foot of sphagnum below this is disintegrated and is mixed with wood. In hole 9 the sphagnum forms a layer 2 feet 10 inches thick, and is raw and brown except for a 6-inch layer (at a depth of 1 foot to 1½ feet) which is dark brown and disintegrated. The fibrous peat in both holes is brown to dark brown and disintegrated to decomposed. The sedimentary peat is brown. The pumicite (1-inch layer) in hole 8 is white; in hole 9 (2-inch layer) it is brown. There is sand at the bottom of both holes. The two grades of sphagnum in the old profile are based on the von Post scale mentioned in chapter II (p. 5). The material shown as lake mud approaches the properties of sedimentary peat.

Ronald peat area

The Ronald peat area (estimated at 25 acres) is in sec. 8, T. 26 N., R. 4 E., just north of Seattle. The roads in the vicinity are numbered as streets and named as avenues on the Seattle system. East 175th Street crosses the northern border of the peat, and Meridian Avenue extends close to its western border, which is about half a mile east of the Ronald business center on U. S. Highway 99. The peat lies in a depression in the glacial drift of the plateau region.

From much of the area south of 175th Street peat has been removed to a depth of 8 or 10 feet by the use of power machinery, and a pond now occupies several acres. The removal of peat has been going on for 15 years or more. Most of this peat has been ground in a mill, stored under cover, and sold by the sack or truckload for use on gardens and lawns. In 1952, peat was being dug and sold by two companies: Plant Food Company, 2303 North 175th Street, Seattle, and Fuller Soils, 17002 Meridian Avenue, Seattle. The peat north of 175th Street is covered with a dense growth of Labrador tea and other bog shrubs.

The map and profile (fig. 61) are redrawn from Rigg and Richardson (1938). When first inspected by Rigg in 1923 this was a sphagnum bog with numerous western white pine trees as much as 40 feet tall and some small cedars. It had a natural swampy brushy marginal ditch around it, and a sedge swamp bordered it on the east. This peat area has also been described by Dachnowski-Stokes (1930), and pollen data were recorded by Hansen (1947).

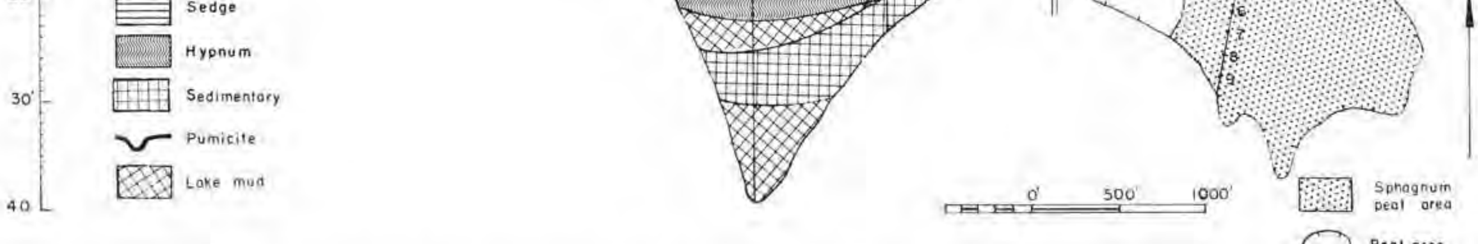


FIGURE 61.—Map and profile of Ronald peat area (25 acres, estimated). Map adapted from U. S. Department of Agriculture soil map of King County.