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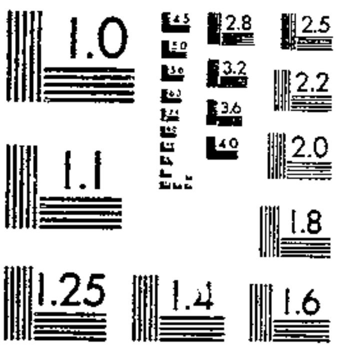

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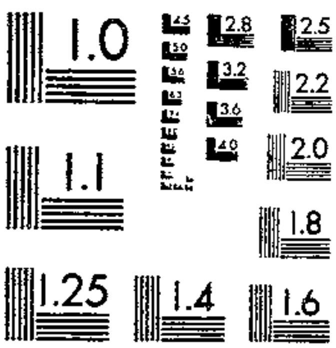

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Peat Resources in Alaska [1]

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(Report of a study made at the request of the National Forest Administration, Forest Service)

CONTENTS

INTRODUCTION

The increasing consumption of commercial peat products for the purpose of adding humus-forming organic matter to mineral soils and for improving soil conditions, for bedding in stables, as poultry litter, in the preparation of composts with waste materials, and for other pur-

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Sincere thanks for cooperation are due also to W. A. Rockie, Assistant Regional Conservator of the Soil Conservation Service; to Dr. D. D. Irwin of the Matanuska Agricultural Experiment Station; Dr. A. H. Bauer of the Alaska Planning Council; Mr. J. P. Anderson, botanist in Juneau, Alaska, who assisted in the identification of plants; to Messrs. S. O. White, H. A. Jensen, and G. B. Banta of the Alaska Game Commission; to Earl N. Ohmer, George A. Lingo, W. O. Geist, Charles G. Lewis, B. F. Moore, and many others both in and out of Alaska who furnished information and extended many courtesies. Grateful acknowledgment is due to R. R. Robinson, Junior Forester, Forest Service, who accompanied the writer in the field, aided in sounding most of the peat areas, and contributed the photographs for this report. The maps were prepared by the Engineering Division of the Forest Service, and the sketches shown in figures 3, 6, 23 and 24 were contributed by Alfred P. D. Stokes, Jr.

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poses, has created a demand for definite information concerning the different types of peat available and also a desire to furnish the trade a substantial quantity of standard grades of domestic moss and sedge peat suitable for various uses.

The state of uncertainty regarding domestic supplies of commercial types of peat of standard quality, including moss peat, and the increasing demand to make the United States less dependent on foreign imports, has forcibly directed attention to the possibilities of utilizing the large peat resources in Alaska. Here muskegs and grassy marshes of various kinds cover large areas estimated at more than 110 million acres. The numerous inquiries which are received by the Department of Agriculture have made it desirable to estimate these resources and to indicate briefly the composition and characteristic properties of several types of peat recognized by the trade, and the methods and difficulties involved in the manufacture of marketable standard grades of peat suitable for the purpose of adding humus-forming organic matter to the soil and improving its condition.

As early as 1909, the United States Geological Survey issued a publication dealing with the preparation and possible use of peat as fuel in Alaska, but no survey or description of peat areas was undertaken at that time. In 1939, in response to the need for information which would facilitate the industrial utilization of Alaska peat deposits heretofore undeveloped, and make possible a coordinated use plan for the natural resources in the Territory, a program of field work was formulated by B. F. Heintzleman, Regional Forester of Alaska, in cooperation with the Bureau of Plant Industry, to determine the location, quality, depth, profile characteristics, and other factors of the potential supplies of peat materials that are accessible and available for commercial purposes and thereby establish a basis for a well-rounded and coordinated development of the Territory's peat resources. The field work was continued for a limited period only; it began May 29, 1939, and was carried on until August 7, 1939.

The methods employed in the investigation were those generally used in field work. Charts of the United States Coast and Geodetic Survey and topographic sheets of the United States Geological Survey served as base maps. Actual examination of the peat areas included profile soundings made from the surface to the bottom of the deposits in order to determine the botanical composition of vertical cross-sections, to describe their physical characteristics, to reconstruct the types of original vegetation and environmental conditions—particularly with reference to the sequence and quality of different layers of peat, and to interpret the inherent structural features and relationships in terms of use capability. The American type of peat sampler—a modification of the Wisconsin instrument employed by C. A. Davis and others—was used and samples of doubtful character were sent to the laboratory for macroscopic and microscopic study.

The results of this preliminary investigation on the character and general condition of peat resources in Alaska are here presented. The report includes a brief statement of the salient features of the peat areas examined in Alaska, and appraisal of the factors bearing on the origin, condition, and characteristics of peat materials connected with the problem of their prospective uses. No attempt is made to discuss costs of excavation, preparation, or sale values of peat products or to enter into the technical and theoretical phases of utilizing the large peat resources of Alaska for commercial or other purposes. It is considered desirable, however, to discuss the underlying principles upon which any successful attempt must be based, to indicate briefly erroneous ideas which have been entertained, and to outline the working methods which have so far been employed successfully. The first part of the report deals with the profile features, development, and varying conditions of Alaska peat deposits. The second part describes the operations necessary in the manufacture of commercial humus-forming peat products for soil improvement.

No claim is made that the following is in any sense a definitive statement. Necessarily, the investigations have been of a preliminary and exploratory nature only. To meet more exact requirements that are certain to arise, additional field work should be undertaken. There is need, among other things, for a series of good aerial maps for south-central and interior portions of Alaska, followed by detailed mapping and a thorough inventory of Alaska's peat resources. A regional experiment station could well be established to determine the possible uses of several kinds of peat of standard quality in the Territory, to investigate further the specific effects to be derived from their use as soil amendments under a variety of conditions, to demonstrate the benefits to be realized from composting with wastes of the fishing and canning industries, and to develop new methods and products. Previous investigations of the value of peat have been, and still are, unsatisfactory because they failed to identify and describe the kind of peat used. The predominance of the salmon fishing and canning industry in Alaska, the expansion of plants for the curing and reduction of herring, and the enterprises connected with raising fur-bearing animals indicate the outstanding commercial importance of these operations as a direct means of livelihood for many inhabitants of Alaska. The adoption of a suitable and economic method of manufacturing and marketing standard types and qualities of peat products and of composting with organic wastes would result in establishing a new industry and in eliminating difficulties that are now attendant upon large-scale production.

RÉSUMÉ OF FINDINGS

The results of the field work done may be summarized as follows:

1. Areas of peat in Alaska are almost everywhere called muskegs. The word is of Indian (Algonquian) origin and applied in ordinary speech to natural and undisturbed areas covered more or less with sphagnum mosses, tussocky sedges, and an open growth of scrubby timber. The use of the word "muskeg" as an ecological term is limited generally to peat-forming vegetation in Alaska and northwestern Canada.

2. Muskegs can be classified into "slope" muskegs, "raised" muskegs, and "flat" or valley muskegs. The names refer to real differences in topographic, structural, and developmental conditions. The attempt to bring the different muskegs found in Alaska into a systematic arrangement approximately expressive of their ecological relations and history must not be considered final.

3. The first group represented in Alaska includes all muskegs which have a sloping surface. This is an oceanic type of muskeg formation. It develops in coastal regions where the peat-forming vegetation is

dependent upon cool summers, high precipitation, and high humidity. The peat material accumulates on gently undulating, sloping land which lies but little above sea level and on slopes of mountain islands. Over much of the general surface hummocks of sphagnum mosses rarely dominate any considerable area; they are only of local occurence. Scrubby conifers are associated with various ericaceous shrubs and conditioned by local changes in water level and aeration. The dominants are usually mixed communities of sedge and moss vegetation in which are prominent *Scirpus caespitosus*, *Eriophorum angustifolium*, *E. vaginatum*, *Rhynchospora alba*, and several species of *Sphagnum*. Essentially the same type of vegetation covers the muskegs in higher plateaus and high lying slopes of mountains. Most of the muskegs began as sedge marshes but often contain, below the present surface, one or two layers of stumps of spruce or pine forests which developed during drier conditions. Slope muskegs are common in the exposed coastal regions bordering the Pacific and certain forelands of Prince William Sound; they are especially prominent on Mitkof Island.

4. The second group in Alaska is represented by the raised muskeg. It is distinguished by the marked convexity of its surface and hummocks of sphagnum mosses which by their continual upward growth lead to the accumulation of moss peat reaching several feet in thickness. High atmospheric humidity and strong acid reaction accompanied by a lack of nutrient mineral salts are the environmental conditions which maintain the growth of sphagnum mosses. Hummocks are colonized by various plants of which *Empetrum nigrum*, *Vaccinium vitis-idaea* var. *minus*, cranberry, and sundew dominate the surface of hummocks while *Rhynchospora* spp. and cottongrass occupy the intervening hollows. Small shallow pools of water are frequent but none of these represent the sites of former lakes or ponds. *Ledum groenlandicum*, *Kalmia glauca*, and *Andromeda polifolia* are the dominant heaths. There is evidence that scrubby heaths and conifers colonize the moss peat of well-drained muskegs. Raised muskegs develop in less extremely wet climatic conditions than those necessary for the formation of slope muskegs. The group resembles the high moors on the European continent. Characteristic raised muskegs are well represented at Juneau, between Seward and Hope, and certain localities in the interior.

5. The third group of muskegs is represented in Alaska by the flat or valley muskegs. The group is closely related to the slope muskegs, from which it differs in environment in its limitation to lowlands, valley streams, and edges of lakes and ponds of which the water is more or less acid in reaction and relatively poor in soluble mineral salts. The surface of these muskegs is flat or concave and their development cannot go beyond a certain height nor can it spread laterally. This is probably correlated with the dependence of the vegetation upon ground waters and its relative inability to grow above the local water table. The normal succession is from aquatic peat-forming plant communities to transitional stages dominated by sedges, rushes, and grasses. The later stages begin with the appearance of characteristic sphagnum mosses and their associates. This is correlated with marginal colonization by heaths and conifers. Any increasing density in shrubs or trees may eventually kill out the sphagnum mosses in the ground cover. Representative muskegs of this

group are located in the Copper River region, in the valleys of the Anchorage district and in the interior.

6. Information on the wildlife of muskegs and the interrelationships between animals and vegetation is very limited. Muskegs show as yet no effect of grazing or the feeding by game and herbivorous fur bearers. There are signs of browsing on tree seedlings and twigs of low deciduous shrubs, and of feeding on berries and other fruits. There is an abundance of shelter and food but, except in southeastern Alaska, the supply may be inaccessible during the long winter months owing to heavy snowfall. Excavated areas of peat, if not used for agricultural purposes, should be ponded and reserved for wildlife.

7. Evidence points to the recent sinking of the shore line in certain places in Prince William Sound, and the subsidence of slope muskegs below sea level at Bomb Point and Fidalgo Bay.

8. Muskegs at Wasilla Lake and in the vicinity of the Matanuska Agricultural Experiment Station contain layers of *Chara* marl below the surface. The calcareous material is of good quality and occurs in considerable abundance; it has potential value for reducing the acidity of agricultural soils and in the manufacture of Portland cement.

9. Among the qualifying factors that affect muskegs in the interior of Alaska are layers of volcanic ash, wind-blown silt, and a permanently frozen condition. The line of permanent frost appears to have been rising periodically. Summer thawing ranges usually between 20 to 45 inches below the surface.

10. The interpretation of profile features of peat deposits has not advanced far enough to permit any definite opinion as to the age or the period of time necessary for the accumulation of different layers of peat in muskegs. There is a possible relation to European post-glacial periods.

11. The areas of peat buried under many feet of stratified silt, gravel, and ice in the valleys excavated near Fairbanks, would seem to represent interglacial periods in contrast to the present muskegs on the surface of the valleys which in all probability developed since the last glacial stage. These valleys are a record of the prehistoric past; they contain valuable fossils of extinct animal life and plant remains of ancient muskegs; they offer a unique opportunity for the scientific study of the natural history of the region, changes in elevation and climate, interglacial stages, and the movements of vegetation and animal life. Portions of these valleys should be reserved by the Territorial government for a study of the record and its important relationships.

12. The agricultural and industrial utilization of muskegs in Alaska should be a part of the regional planning in which various interests are considered and adjusted. Several territorial and Federal agencies could participate in a coordinated program. A more detailed and comprehensive survey of Alaska peat deposits, in all its aspects, should be included in the series of regional planning studies made for the development of the resources of the Territory.

13. The presence of ever-frozen muskegs and mineral soils in the interior has not attracted many to agriculture. Nevertheless, the depth to which surface layers of soil and peat thaw during the short but warm and dry summers and the reservoir of moisture they constitute, have decided advantages. According to settlers, crops such as rye, oats, barley, wheat, many kinds of vegetables and good pasture

grasses grow remarkably well and never suffer from drought during the growing season where frozen subsoils are melting.

14. Montana Creek muskeg near Juneau, Moose Lick muskeg on the road between Seward and Hope, and the muskeg near College in the Fairbanks district contain surface layers of sphagnum moss peat which are of good quality. They are suitable for commercial uses and as a source of supply for continental United States. The thickness and purity of the material depend largely upon the particular environmental conditions where the accumulation occurred.

15. Most of the muskegs in Southeastern Alaska and in Prince William Sound consist of sedge peat. A good quality of commercially important sedge peat occurs at Petersburg, in Hamilton Bay, and other localities. It is overlain by sphagnum moss peat varying in thickness from 8 to 20 inches. Other types of peat, such as woody peat, hypnum peat, and sedimentary peat occur in minor quantities.

16. The second part of the report discusses the current demands for sphagnum moss peat and sedge peat as a source of humus-forming organic matter for soil improvement. Field operations are described relating to practical working methods such as draining, excavating, drying, shredding, and packing. Selection of a few accessible deposits containing a good quality of moss or sedge peat, a uniform grading system, and maintenance of standards of quality would avoid difficulties and mistakes of past commercial attempts. It would also benefit the research that should be undertaken to serve as a basis for the intelligent use of standard types and grades of peat materials under various soil and cultural conditions for the growth of plants or for other purposes.

GENERAL FEATURES OF THE PEAT DEPOSITS

Alaska has an area of about 586,000 square miles or about a fifth that of continental United States. It has a variety of climates, land forms, and vegetation and may be divided into six principal regions each with distinct characteristics and various natural resources including different kinds of peat. A general inventory of existing land resources shows that about 70 percent of the total area of Alaska is covered with vegetation of which about 50 million acres has trees sufficiently dense to be classified as forest, approximately 100 million in tundra, and nearly 110 million in muskeg and grassy marshland (*41*).[3] The Territory is almost wholly in Federal ownership and studies are under way for a careful planning of the use of these land resources and for vigorous measures of conservation.

Alaska has two national forests, administered from a regional office of the Forest Service in Juneau. The Tongass National Forest includes the greater part of southeastern Alaska, and the Chugach National Forest covers the timber belt on the shores of Prince William Sound.

In Alaska the terms "tundra" and "muskeg" have no satisfactory geographic or descriptive definition and there is a prevalent confusion as to what constitutes a muskeg. This is true both in common parlance and in various publications which have described the vegetation of the Territory. While the term "tundra" covers all treeless vegetation of whatever type and is applied to a wide range of both

[3] Italic numbers in parentheses refer to Literature Cited, p. 82.

organic and inorganic material, as shown on a map prepared by the United States Soil Survey (*40*), the so-called muskegs appear to have greater significance with reference to a very definite mode of origin and structural formation. The term "muskeg" is of Indian (Algonquian) origin denoting an area covered with sphagnum mosses and tussocks of sedges. It seems best, for the present, to let the distinctions between different kinds of muskegs rest on the individual descriptions given in this report.

Before giving any detailed evidence for the character, composition, and stratigraphic features of the separate muskegs in Alaska, it will be desirable to outline some of the basic facts and methods on which the conclusions rest.

It is no longer necessary to explain the several lines of inquiry and the methods of field work appropriate for a study of peat deposits that may be applied to an analysis and classification of the various kinds of organic material which they contain. Such information has been set out in earlier publications (*9*, *13*, *14*). It will be recalled that the most obvious method of determining the main character of primary peat materials is based on the external form and the botanical identification of the plant remains which are sufficiently well preserved to be recognizable. Peat materials of relatively uniform composition and purity represent a type and are classified as woody, fibrous, or sedimentary. Those grouped as woody include coarse, lumpy, partly decomposed woody fragments, irregular to angular in shape, leaves, needles, bark, bits of twigs, roots, and other components of trees and shrubs, as well as woody granular material, the coarseness or fineness depending on the degree of decomposition. The peat materials grouped as fibrous consist of underground stems and roots of grasslike plants which show more or less well developed horizontal cleavage plains or lamination, while those derived from entire small stems, such as sphagnum mosses preferred for commercial use as stable bedding or packing and shipping seedlings and cuttings, are often characterized by small columnar lumps and vertical aggregates. The third group includes all peat materials which are more or less colloidal or jellylike, form a coherent and sticky mass, shrink greatly and become hard upon air-drying, and represent finely divided organic sediments that accumulated in open water from aquatic vegetation.

The terms "muck" and "peat" have often been used indiscriminately in literature. The term "muck" is properly used when it refers to any peat material that has been altered by drainage and aeration, the action of micro-organisms, or cultivation and consequently has advanced in stage of decomposition so far that its botanical character is no longer evident. According to its origin muck may be designated as reed muck, sedge muck, etc., the name referring to the type of peat which has undergone decomposition. Muck is residual peat material; it is usually granular in structure and the components are relatively loose and more or less rounded in shape. The breaking-down process may proceed to complete pulverization. Muck is generally dark brown to black in color; it differs in the quality of its residues, is relatively low in absorbing capacity for water and soluble salts, and the mineral content may range between 5 and 35 percent. Muck which contains more than 40 percent of mineral matter should not be confused with the well-decomposed and mineralized organic matter in soils which is synthesized by micro-organisms and spoken of as humus. Information on physical and chemical properties of different kinds of peat is given in Circular 290 (*12*). Analytical data of entire peat profiles from various sections of the United States are discussed in Technical Bulletin 214 (*16*). Adequate structural and comparative field descriptions upon which developmental views may be based, and coordinated laboratory tests of samples from the entire depth of a peat area constitute the means to draw correct conclusions as to the main process and conditions which give rise to differences in vegetative cover, in stratification or arrangement of layers of peat below the surface, and in the main properties of the various peat materials.

The most distinctive features of an area of peat are its strata, which differ in quality according to the character of the peat-forming vegetation and the content of mineral or other constituents and useless or harmful matter. Thus the successive layers of peat in a deposit reflect the changes in the composition of the vegetation which replaced one another in a peat area throughout the whole period of its formation (*24*). By the comparative examination of plant remains and the stratigraphic sequence of peat layers of muskegs all over Alaska, it has become possible to establish a coordinated history of the complex development which the muskegs have followed in response to changes in climatic conditions, in water table, and in supply of soluble salts affecting physiological and other vital processes, as well as to effects of drought, fires, floods, and erosion. In this way an analysis of the peat layers superimposed upon one another may be employed also as a chronological scale against which other events, such as climatic cycles, volcanic eruptions, or changes in sea level, can be measured (*10, 11*).

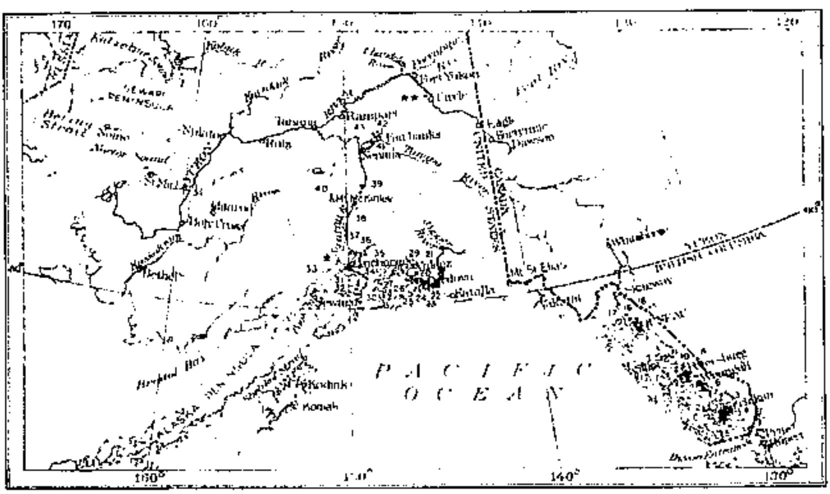

FIGURE 1.—Numbers and approximate location of muskegs examined in Alaska.

The map shown in figure 1 indicates the location of the muskegs by name and number examined in Alaska and presented in this report.

PEAT RESOURCES IN SOUTHEASTERN ALASKA

Most of southeastern Alaska lies within the Tongass National Forest. The dominant feature of this region is its mountainous character. Brooks (*4*) has described some of the geographic features. It comprises a narrow mainland strip of the coastal mountain range and a chain of islands separated by a network of deep marine water courses. On the islands the mountains rise to heights of 4,000 feet and on the mainland the peaks reach in places more than 10,000 feet above sea level; they extend southeasterly from the main body of the Territory and along the west side of British Columbia. The islands, viewed from the waterways, are mountains which rise sharply from the water's edge. The largest of these are Prince of Wales, Chichagof, Baranof, Admiralty, Kupreanof, Kuiu, Revillagigedo, and Mitkof. The land forms indicate results of extensive Alpine glaciation, the special features of which are Matterhornlike peaks, U-shaped and hanging valleys, cirques, and fairly extensive flat and wide lower valleys. There is little level land.

Because of the rough topography only short roads have been constructed in towns and adjacent settlements. The region is most accessible by steamers which operate through the Inside Passage between Seattle, Vancouver, and Alaskan ports, and by airplanes and motor-driven launches used to reach intermediate places.

Southeastern Alaska is the most highly developed part of the Territory; it contains one-third of the total population, the greater amount of the fishing and canning industries, and a dense growth of forests of which the larger bulk is commercial timber. The principal towns are Juneau, Sitka, Ketchikan, Petersburg, and Wrangell.

The climate of southeastern Alaska is mild, being moderated by the warm ocean currents of the northern Pacific. The summers are cool and the length of the growing season is about 160 days with long daylight in June. The period of heaviest precipitation is from the latter part of August to December and the least from April to July. It is heaviest on the islands in the southern part of this region, diminishes northward, and appears to be much greater on the mountain slopes than at sea level. The total number of rainy days in a year average 160. There is no evidence of any accumulation of snow in the glaciers, most of which appear to be receding very slowly. The prevailing winds come from the south and southwest, and northerly winds almost invariably bring fair and dry weather. The winter temperatures at sea level are comparable with those on the Atlantic Coast. The lowest sea-level temperature on record at Juneau is $-15°$ F., at Sitka $-5°$ F., and at Ketchikan $-8°$ F. However, owing to the northerly latitude, the minimum temperatures drop rapidly with increase in elevation above sea level and with distance from tidewater.

There is little agriculture in southeastern Alaska. Most of the small areas under cultivation are near towns, at the head of some bays, and on the tidal flats of which the grasses are used as forage for livestock. The lower slopes of the mountains are timbered. Dense forests of hemlock (74 percent), spruce (20 percent), "cedar," pine and other species (6 percent) cover practically the whole area to altitudes of 2,000 to 3,000 feet (*37*). A growth of scrubby conifers, alder, and willow extend in places 1,000 feet beyond these altitudes associated with alpine vegetation, glaciers, and waterfalls. Scattered through the forests and in the foothills, on the flats or benches and along the shore, occur areas of peat generally called muskegs and covered with vegetation consisting of sedges, sphagnum mosses, heath shrubs and scrubby lodgepole pine, "cedar," or spruce. A map giving essential data regarding the distribution of peat areas examined in this region is shown in figure 2.

Muskegs of the Ketchikan District

The Ketchikan District forms the most southern portion of the Tongass National Forest. It includes several islands, the larger of which are Prince of Wales, Revillagigedo, and Gravina.

REVILLAGIGEDO ISLAND

Revillagigedo Island is in the extreme southeastern part of Alaska. Ketchikan, on the southwest coast of the island, is the leading port of entry; it has a number of salmon canneries and is an important center for frozen and iced fish shipped to eastern markets.

The island is separated from the mainland by the Behm Canal, and from Prince of Wales Island on the west by Gravina Island, Cleveland Peninsula, and Clarence Strait. The shore line is very irregular and deeply indented. The surface of the island is mountainous, varying in relief from 1,500 to 4,560 feet. The whole aspect of the landscape is characteristic of a glaciated region. Most of the island is heavily forested practically from the water's edge up to an altitude that may reach about 2,500 feet, depending upon local conditions. A relatively small percent of the lowland and lower slopes of valleys has features that are characteristic of muskegs and other types of peat land. They vary in size and as to possibilities for commercial use.

KETCHIKAN (NO. 1)

In constructing the Tongass Highway, a road from Ward's Cove to the lakes at the upper end of the Ward Creek drainage, a cut was made through a muskeg (No. 1 in figs. 1 and 2) which shows the curved surface that is given to a peat deposit by the upward growth of sphagnum mosses absorbing and holding rainfall. The peat area is one-half mile northeast from Ward Lake or approximately 8½ miles northeast of Ketchikan and at an elevation of about 50 feet above sea level. It covers less than 2 acres and occupies a troughlike depression scoured out of the rock by ice. The muskeg has a well-marked convexity (fig. 3), with margins sloping down to the forest floor, and supports a ground cover which consists of low cushions alternating with hollows formed by the growth of different species of sphagnum mosses. Typical species are *Sphagnum cuspidatum* in the wetter habitats with an occasional species of *Rhynchospora*. On the drier and firmer portions of the hummocks occur *S. fuscum*, *S. rubrum*, *S. squarrosum*, and others. The latter are characteristic primary peat-formers of the mosses which cover the area. Associated with them are herbaceous plants such as *Scirpus caespitosus*, *Eriophorum* sp., *Drosera rotundifolia*, *D. intermedia*, *Empetrum nigrum*, cranberry, low blueberry shrubs, and others. This community is in an actively growing condition and colonized by small heaths such as *Ledum groenlandicum*, *Kalmia polifolia*, *Andromeda polifolia*,

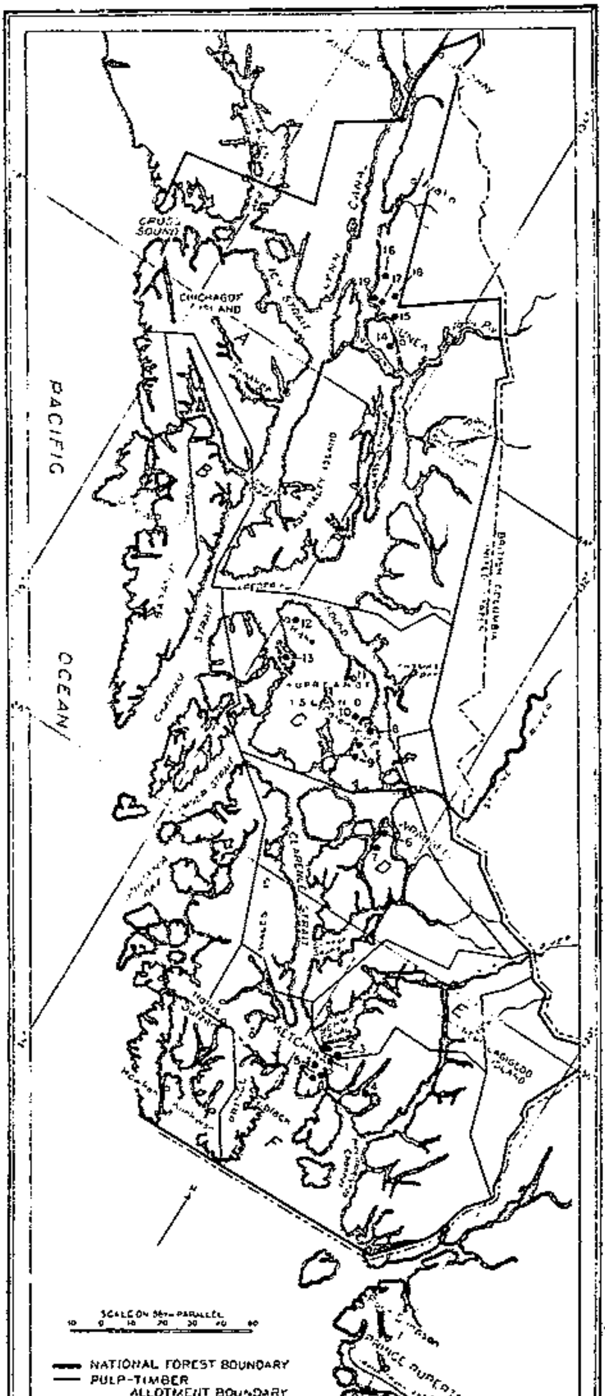

FIGURE 2.—Distribution of the muskegs examined in major districts of southeastern Alaska. National forest and pulp-timber allotment boundaries are shown. Numbers of muskegs correspond to numbers in figure 1 and in headings of descriptive matter to follow.

Vaccinium uliginosum, and a scattered dwarfed growth of lodgepole pine (*Pinus contorta*), Alaska yellow-cedar (*Chamaecyparis nootkatensis*), and mountain hemlock (*Tsuga mertensiana*)—the latter low and fan-shaped. They give the area the aspect of raised moors described in former publications (*13, 14, 29, 33*).

Profile soundings made on the west side of the road, as well as cross sections exposed in the cut, indicate three distinct layers of peat as follows:

0–2½ feet; moss peat. The material in the hummocks consists of vertically elongated components and is typically spongy for the first 8 inches shading from a yellow-brown to reddish-tinted moss peat below the first foot level; in the deeper central portion of the peat area, the surface material to a depth of 18 inches consists of reddish-brown, spongy, compacted moss peat, relatively well-preserved, having a reaction of pH 4.0; it is followed by thin seams of darker-colored moss peat in an advanced degree of decomposition, representing probably the plant

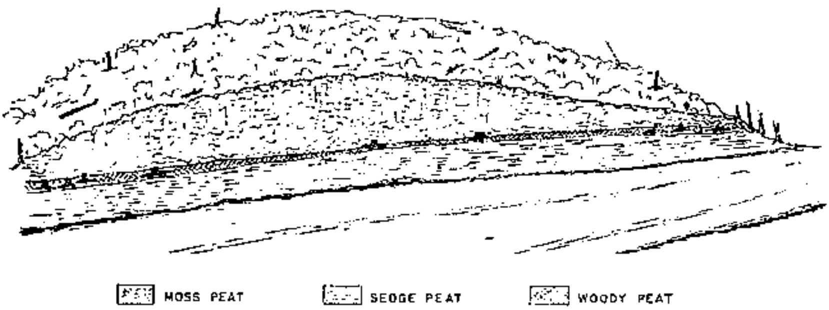

FIGURE 3.—A muskeg near Ketchikan, showing characteristic convex surface sloping from the center towards the margin where it merges with trees of the surrounding forest.

remains of a hollow depression on which, later, a hummock developed; the layer slopes toward the margins, is thinner at the edges and contains small amounts of woody roots from cranberry and shrubby heaths; on the east side of the road the content of woody material is larger. The lower portion of the layer has an admixture of roots and rhizomes from cottongrass and other sedges, is grayish brown in color, slightly decomposed, and contains dark colored organic residue.

2½–3 feet; brown woody peat with stumps and roots of conifers and rootstocks of heaths; the layer is thinner in the central portion and more fibrous from plant remains of tussocky sedges; in places it contains a litter of needles and leaves of heaths showing very little disintegration; the material is acid in reaction.

3½–6 feet; sedge peat, yellowish brown in color, more or less matted fibrous and definitely horizontal; it consists principally of rootlets and underground stems from a variety of sedges; at the lower level the material tends to be crumbly and contains herbaceous plant remains, thin woody rootlets, seed capsules, bits of bark and twigs and scales of insects; the layer is fairly sharply demarked from the underlying mineral substratum.

6–6½ feet; dark gray micaceous sand which contains well-decomposed organic residue with a reaction of pH 5.8.

In the stratigraphic development of the raised type of muskeg it is evident that a marsh of grasses and sedges was replaced by a scrubby forest and later succeeded by sphagnum mosses which gave rise to a convex surface.

POINT HIGGINS (NO. 2)

Contrasting sharply with the Ketchikan raised muskeg is the flat area of peat between rock outcrops near Point Higgins on the Tongass highway. It is an example of a local type of muskegs determined by ground water overlying an impermeable rocky plateau where drainage is impeded. The surface is relatively flat, and the ground cover of sphagnum mosses is thin and not continuous. The area is timbered, the principal species being western hemlock (*Tsuga heterophylla*), lodgepole pine, and Alaska yellow-cedar. The trees are slow-growing and usually quite limby. Among the heaths, the lowbush blue berries (*Vaccinium caespitosum*, *V. uliginosum*) and the mountain cranberry (*V. vitis-idaea* var. *minus*) are relatively abundant with various sedges, notably *Scirpus caespitosus*, which occur in patches and dense clusters. In general the flora indicates a transition in which trees predominate and tend to encroach on heaths and their associated sedges. Spaghnum mosses have not succeeded in forming a distinct layer of moss peat.

The profile features of this muskeg are quite complex. Soundings made in sections where moss hummocks occur, give the following record:

0–10 inches; the upper 6 inches consist of mosses which merge with yellowish-brown fibrous sphagnum moss peat; the material contains fine roots and underground shoots of cranberry (*Vaccinium oxycoccus*, *V. vitis-idaea* var. *minus*), crowberry (*Empetrum nigrum*), and Cloudberry (*Rubus chamaemorus*); the lower 4 inches are moist and roots of heath shrubs are abundant; in the denser wooded portions of the area, there is a well-developed root and stump level to the depth of 18 inches; the roots of standing timber are growing horizontally and distinctly flat based;

10–36 inches; reddish-brown, matted sedge peat, partly decomposed; it contains plant remains from sphagnum mosses; near the second foot level it consists of dark-colored material with woody roots of trees and shrubs; the lower portion of the layer is sedge peat free from woody fragments, saturated with water and acid in reaction;

3–7 feet; water pocket; contains brownish-colored organic residue in suspension;

7–8 feet; brown fine-grained sticky sedimentary peat;

8–10½ feet; dark-brown matted fibrous sedge peat acid in reaction; woody material and thin seams of sandy fine-grained organic residue are more frequent toward the bottom;

10½–12 feet; greenish-gray fine sand with plant remains from woody shrubs, grasses, and sedges, grading into dark-colored micaceous sand and, at lower levels, into bluish-gray sandy clay.

Starting with the oldest layer, the development has been from a sedge marsh which supported woody shrubs, indicating that the water level was low at the primary stage. Later a rise of the water table occurred, expanding to the size of a small lake or pond in which sediments accumulated from aquatic plants. A floating mat of sedges contributed to a layer of sedge peat unable, however, to fill completely the body of water. Sphagnum mosses invaded at a more recent period, but trees near the edge of the muskeg advanced upon the peat area and maintained themselves effectively under present surface conditions.

PERSEVERANCE (NO. 3)

Among the more interesting types of muskegs are those which cover slopes of hills and of mountains. They represent a type that may well be called slope muskegs. Characteristic examples are the muskegs which occur along the trail to Perseverance Lake at points about 1,000 feet and 2,000 feet from its junction with the road to the second Ward Lake.

The muskegs have in general a gentle slope and conform to the topography of the foothills. The surface irregularities possess characteristics that are due to shallow pools of water which show no indication of drainage. The dominants are sedges, usually mixed with sphagnum mosses. The trees are mostly lodgepole pine and hemlock, "cedar" being less abundant; they grow scattered, low and dwarfed; although in the open, their lower branches continue to die from unfavorable soil and ground-water conditions. The shrubs are small and dominated by heaths. Herbaceous plants and sedges are conspicuous, the following plants being prominent: *Scirpus caespitosus*, *Eriophorum* sp., and *Rhynchospora* sp. They constitute a more important characteristic of the ground cover than sphagnum mosses. Any noticeable convexity of surface is generally due to the rounded topography of the underlying mineral substratum.

The profile sections, obtained by sounding the small area along the trail about 2,000 feet from the road, are typical of slope muskegs, as follows:

0–1 foot; thin cover of light-brown fibrous sphagnum moss peat showing no appreciable differentiation from the color and texture of the growing mosses; it varies in thickness from 3 to 5 inches; the material overlies a thin seam of dark-colored sedge peat which contains an admixture of sphagnum mosses and the woody roots and shoots of heaths; the material below it consists of dark-brown fibrous sedge peat much of which is waterlogged, giving a reaction of pH 4.5 to 5.0.

1–7½ feet; brown fibrous-matted, somewhat felty-fibered sedge peat; between the 4 and 5 foot level, the layer contains woody fragments from shrubs and conifers; it grades into a compacted yellowish-brown fibrous sedge peat; at the 7-foot level, the material is dark brown in color, in an advanced degree of decomposition and crumbly when dry; it grades sharply into very dark-brown sandy organic residue;

7½–8 feet; firm dark-gray micaceous fine sand; very compact at the lower level.

THORNE ARM (NO. 4)

Another notable contrast to muskegs of the raised and the flat lowland group is an area of peat which occupies a slope about a quarter of a mile inland on the west side of Thorne Arm bisecting Revillagigedo Island. The muskeg lies near the head of the bay and is reached by a trail. The peat area is best defined by its vegetation cover as that of a transition stage from a moss-sedge marsh to a succession of low heaths. The surrounding timber consists largely of Alaska yellow-cedar, with Sitka spruce (*Picea sitchensis*) and western hemlock The shrubby undergrowth represents an open growth of heaths and the herbaceous cover includes, aside from *Scirpus caespitosus*, *Eriophorum* sp. and *Rhynchospora* sp., such plants as *Caltha biflora*, *Menyanthes trifoliata*, *Sanguisorba officinalis*, *Lysichiton americanum*, *Nephrophyllidium crista-galli*, *Gentiana douglasiana*, *Viola palustris*, *Trientalis arctica*, *Coptis asplenifolia*, *Cornus canadensis*, *Lycopodium* sp., *Limnorchis* sp., *Veratrum* sp., and others. The area is dotted sparsely with a few hummocks of sphagnum mosses and small pools of shallow water which, like the pools of most sloping muskegs give a reaction of pH 5.3 and are poor in aquatic plants.

Soundings show the following cross section:

0–22 inches; the upper portion of the layer represents a thin cover of moss peat imbedded in closely matted roots of the growing grasses, sedges, and herbaceous plants which merge into brown fibrous sedge peat; the lower portion contains the woody shoots and roots from adjacent heaths, some of the roots extend as much as 18 inches below the surface; the extent and character of roots and the marked development of herbaceous plants are probably due to favorable aeration, although the medium acid reaction (pH 5.5) and composition of the ground water are, undoubtedly, also involved; below the 18-inch level the material consists of brown fibrous sedge peat which is very compact and slightly sandy at the lower level.

22–27 inches; dark gray silty and sandy organic residue, very compact and grading into loose gravel; no certain indication of bedrock.

It is to be observed from the profile features that, while the lower portion of the layer is more typically sedge peat, the upper portion represents material of a transitional character; it is not typical of sedge peat in the proper sense but of the plant remains of a stage the succession of which may have significance as an ecological unit and as an important and valuable adjunct in the maintenance of wild, fur-bearing animals. Considerable opportunity exists on the various islands for the expansion of herbaceous plants including deergrass (*Scirpus caespitosus*) which can provide a variety of food and shelter for some forms of wildlife.

GRAVINA ISLAND MUSKEGS (NO. 5)

The topographic features of Gravina Island are similar to Revillagigedo Island, from which it is separated by Tongass Narrows. The island forms a comparatively low, timbered mountain mass west of Ketchikan, with bedrock exposed along its northeastern and northwestern shore. Some of the muskegs, which developed on benches with a gentle seaward slope, rest generally on rock, are shallow, and conform to the topography of the rock bottom; others are flat and consist of peat layers that are more or less horizontal and independent of the configuration of the underlying substratum, while a few show surface layers with a marked convexity.

The irregular-shaped muskegs on the slopes of Gravina Island are less accessible but of greater depth than those near the shore. The structural features of profile sections are typical of the slope muskegs on the trail to Lake Perseverance. The sphagnum moss peat at the surface is thin and not continuous. Peat-forming sedges have been of greater importance than woody shrubs and trees and have played a large part, although there is evidence that trees are now advancing into the muskegs which were originally treeless.

The muskegs on the slopes at higher elevations, particularly those about 1,500 feet from the marine station and in a direction along the pipe line as far back as the dam and water reservoir, lack definite boundaries. They have the aspect of a sedge marsh from the number of sedges and grasslike plants. The vegetation includes *Loiseleuria procumbens*, *Geum calthifolium*, *Menyanthes trifoliata*, *Sanguisorba officinalis*, *Pinguicula villosa*, *Tofieldia intermedia*, and others. Sphagnum mosses form a thin and irregular surface cover and show clearly that atmospheric humidity and high water-table conditions are not the only factors which condition the spread of this type of vegetation. From the distribution of the many small pools of water, which are only pH 5.5–6.0 in reaction, it is probable that the content of soluble salts in the ground water is the limiting factor unfavorable for the growth of sphagnum mosses. The rhizomes of sedges are spreading on the waterlogged surface and appear to have little competition. Heaths are of limited occurrence. Among the shrubs are *Myrica gale* and a dwarfed form of *Juniperus communis* var. *saxatilis*. But the profile sections furnish a clearer distinction in stages of plant succession than the erratic character of the surface vegetation. The profile structure, reflected by soundings, has the following features:

0–1 feet; upper 3 inches yellowish-brown sphagnum moss peat grading into a dark-brown mixture of sedge and moss peat in which woody shrubs are rooting; the layer is saturated with water and gives a reaction of pH 4.5–5.0.

1–7 feet; brown fibrous sedge peat; at the 3-foot level the material is coarsely fibrous, grading into dark-brown sedge peat which contains woody fragments and coniferous timber between the 5¼ and 6-foot level; below it the sedge peat is grayish brown in color, moderately decomposed and contains small angular stones resembling slaty (graywacke) talus;
7–8 feet; rough angular stones over bedrock.

The profile shows a distinct drying effect between the 5½- and 6-foot level where the sedge peat is partially decomposed and gives evidence of the position of stumps of an earlier forest.

Muskegs of the Petersburg District

The area in the Petersburg district of the Tongass National Forest comprises Wrangell, Mitkof, Kuiu, Kupreanof, and several other seaward islands. In general aspect, the topographic character of this portion differs somewhat from that of the Ketchikan district to the south. The coast line of these islands is broken by bays, coves, and channels marked by low-lying hills that rarely exceed 1,000 feet in altitude. The hydrographic maps of this district show numerous inlets and many protected channels. These border land surfaces with gradual slopes and gently arched backs, from the head of the bay toward the steeper slopes some distance from the shore. One of the striking features is the shallowness of many bays and inlets. The floors of the sloping lowland appear to consist generally of bedrock overlain with gravel, cobbles, sand, and silty clay brought down by rivers and glaciers. They are covered more or less effectively with forests and muskegs with a sloping surface. The peat-forming vegetation depends upon atmospheric moisture for its mode of development and is in a sense a climatic formation independent of local ground-water supplies and the nature of the underlying mineral substratum. Thus slope muskegs are related to much the same cool and moist climatic conditions as raised muskegs, except that the vegetation of the latter is more highly specialized and that ground water poor in nutrient salts is an indispensable condition for a continual growth of sphagnum mosses.

Wrangell Island

On Wrangell Island, as generally in the Petersburg district, a few types of slope muskegs have been observed that are of a character intermediate between sedge marshes and sphagnum moss bogs. Their peculiar features are discussed in the profile descriptions given below. Muskegs of the raised type and herbaceous sedge marshes have not been seen in this section of Alaska.

WRANGELL (NO. 6)

On the north side of Wrangell Island, near the town of Wrangell, there are several small muskegs none of them exceeding a greater depth than 8 feet. Some of the areas are near the shore and others are confined to slopes of rounded topography. The mountain sides are covered with conifers but on the peat areas the trees are scattered and dwarfed in growth. Sphagnum mosses are common but of limited local occurrence, supporting various heaths and herbaceous plants.

Profile sounding, confined principally to the areas along the eastern town limits of Wrangell, may be considered to reveal fairly typical

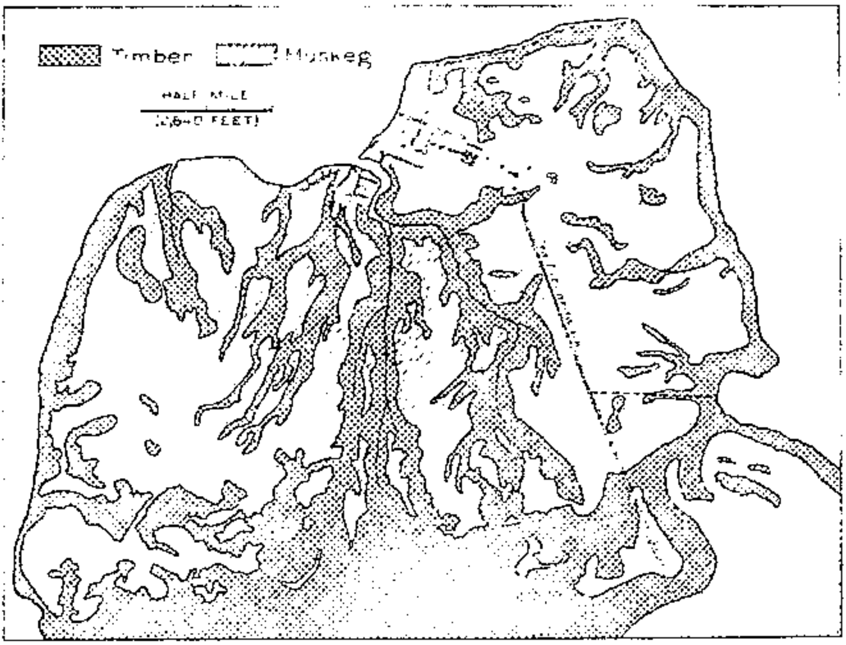

FIGURE 4. Map sketched from aerial photograph showing size, distribution, and accessibility of muskegs at Mitkof Island. Scale: 3.15 inches to the mile.

FIGURE 5.—Oblique aerial photograph of muskegs on Mitkof Island in the vicinity of Petersburg.

examples of the successive stages of vegetation and the corresponding superposition of layers of peat that formed the shoreward type of muskegs. Cross sections observed in a number of places and exposed along roads and newly cut ditches reveal the following features:

0–10 inches: upper 2 to 3 inches straw-colored spongy sphagnum moss peat which grades sharply into grayish-brown partly decomposed moss peat, pH 4 in reaction, and about 7 inches in thickness; below it are spruce stumps with flat based roots, and the woody shoots of heaths.

10–65 inches: brown fibrous sedge peat somewhat compressed and more or less cohesive from the presence of finely divided organic residue, having a reaction of pH 4.8–5.0; between the 38- and 42-inch level are stumps of conifers buried within the sedge peat; the woody roots are flat and rest on fine, partly decomposed, dark-brown sedge peat; at the 50-inch level the sedge peat is reddish-brown, matted, more or less felty fibered; near the 60-inch level the sedge peat contains sand and merges into a sandy, gravelly mineral substratum.

SKI TRAIL (NO. 7)

On the slope of the mountain east of the Wrangell Indian Institute is a muskeg locally known as "Ski trail." Much of it for 2,000 feet up the trail is treeless and moss-covered. Over considerable portions of the surface the heaths are small and inconspicuous and the shallow pools have no drainage. The borders show in some places dense clusters of pine, hemlock, and "cedar;" in other places there seems to be evidence that trees were killed by local fires.

From soundings made at points between the upper and lower portion of the Ski-trail muskeg, the structural features of cross sections may be characterized as follows:

0–18 inches: reddish-brown spongy-fibrous sphagnum moss peat; in places the material contains charred woody fragments and thin black seams of charred moss peat; at the lower level are occasional woody roots of conifers and heaths embedded in moss peat which varies in degree of decomposition; the reaction is strongly acid.

18–56 inches: brown matted fibrous sedge peat; it consists of fine roots and flattened underground stems from various sedges and is definitely laminated; between 36 and 40 inches below the surface occur stumps and flat roots of conifers overlying a dark-brown partly decomposed sedge peat; the material grades into firm reddish-brown fibrous sedge peat which contains a sandy admixture near the 56-inch level and rests on

56–60; sandy gravel of the character of unoxidized glacial till with erratic boulders.

MITKOF ISLAND

The most extensive and commercially important acreage of muskegs is that on Mitkof Island, located 111 miles northwest of Ketchikan and 108 miles southeast of Juneau. The accompanying sketch map (fig. 4), drawn from aerial photographs (*34*), shows the size, accessibility, and distribution of these areas of peat. The oblique aerial photograph (fig. 5) shows the muskegs along the harbor and the channel of navigation. In general the muskegs on the island slope at a low angle and the relief conforms to the underlying rock structure. The town of Petersburg, overlooking Wrangell Narrows, which separates Mitkof from Kupreanof Islands, is located on the seaward extension of a sloping muskeg. Its principal industry is fishing for halibut, salmon, crabs, and shrimp, and raising fox, mink, and other fur-bearing animals.

PETERSBURG (NO. 8)

Exposures along Front Street and Hogue Alley within the town limits reveal profiles that shrank greatly upon drainage; a typical section of these exposures is as follows:

At the base is unconsolidated and unoxidized bluish-gray glacial clayey and sandy gravel; the upper portion of it consists of a thin seam of sandy sedge peat which contains roots and rhizomes from *Scirpus caespitosus*, tussocky sedges, *Equisetum* sp., and herbaceous plants, seeds of *Menyanthes trifoliata* and thin woody roots. Above the glacial till is reddish-brown fibrous sedge peat, matted to felty fibered and more or less laminated; the layer is compressed, stands up

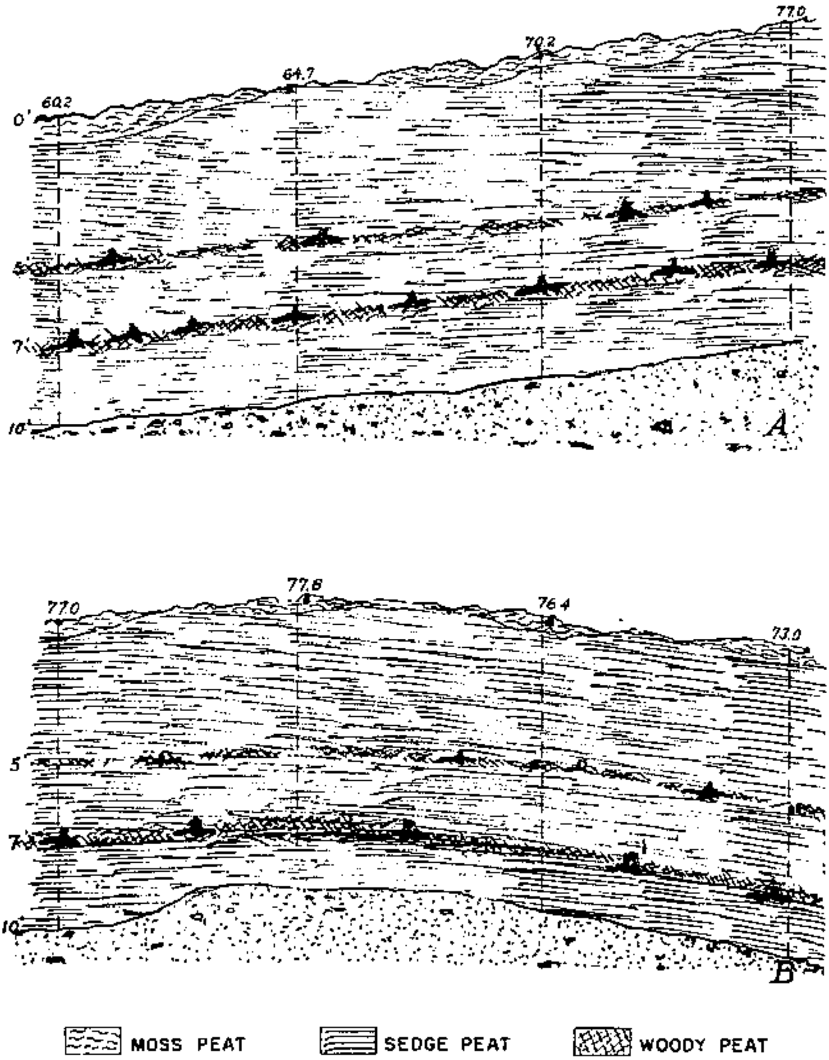

FIGURE 6.—Structural cross section of muskeg at Petersburg, showing bottom topography and sequence of peat layers along a line (*A*) parallel with the slope and (*B*) at right angles to it. Numbers at top correspond to locations of profile soundings. Elevations are based on one common datum of sea level.

well in vertical-walled ditches and excavations, and has a thickness of 6½ feet. It contains flat-rooted stumps of conifers at two distinct levels: the lower stand of stumps is relatively dense, about 1½ feet above the glacial till and characterized by needles, bark, cones, and woody fragments from pine, "cedar," and hemlock; the upper one represents a scattered light stand of timber approximately 3 feet above the mineral substratum. The present surface vegetation, before its removal, consisted of dwarfed pine in a ground cover of sphagnum mosses, heaths, and other plants common to muskegs in this locality.

On the basis of preliminary soundings and observations in open ditches and cut banks in various other parts of the town of Petersburg, it was decided to substitute for the records of individual profiles a set of transect cross sections (*11*) in an undrained area and thus to measure the degree of variation in profile features and determine the general course of formation and development.

The area selected comprised 5 acres. It is located in T. 58 S., R. 79 E., between sections 27 and 34, on a slope above the northern town limits where peat land conditions were relatively uniform. Beginning at lot corner B 55 near H str., 31 individual stations were established in the form of charted quadrats, 6 feet square, and placed at intervals approximately 250 feet apart. Their location and elevation above sea level (mean high water) were determined with the aid of a surveyor's chain, Abney level, and forester's compass, respectively. The general sequence of peat layers, as a whole, is presented in the diagrams shown in fig. 6, which are intended to provide in graphic form the profile features that characterize the northern line of the area parallel with the slope, and the eastern line at a right angle with the slope. In this, an attempt has been made to furnish not only the necessary information for intensive planning, but also to show the character of the different types of peat superimposed upon one another and their relation to the contour of the underlying mineral substratum.

The profile characteristics may be described as follows:

0–16 inches; sphagnum moss peat, usually spongy in texture; the upper portion, in contact with precipitation moisture is yellowish to reddish-brown in color, is well preserved, conserves rainfall, and has a reaction of pH 4.0; the layer does not occur uniformly but varies in thickness and rarely exceeds more than 16 inches in depth; the lower portion, which is generally at the level of the fluctuating ground-water table, shows an admixture of roots from sedges and cottongrass (*Eriphorum* sp.) and includes the woody shoots and roots of growing heaths such as *Empetrum*, *Ledum*, *Andromeda*, *Vaccinium*, and the flat roots of small conifers (*Pinus contorta* and others); decomposition produces a darker color and alterations in texture and water-holding capacity.

16–50 inches; sedge peat; the layer is of good quality and consists essentially of a matted network of fine roots and flattened underground stems derived from a variety of rushes and grasslike sedges (*Carex* sp., *Scirpus* sp.); the material is brown in color, coarse to felty fibered, more or less laminated, and generally promotes infiltration and storage of water, a high-water table, and a reaction ranging from pH 4.5 to 5.5.

50–56 inches; woody peat, made up chiefly of stumps and roots of conifers, coarse woody fragments from branches, bark and small shrubs, with varying amounts of plant remains from sedges; the material is dark brown in color and represents a sparse growth of timber under conditions of lowered water levels which favored aeration and a fair degree of decomposition.

56–96 inches, sedge peat, brown, finely fibered, firm, tending to become brittle when dry; the plant remains are more or less clearly discernible in the coarser fibrous, yellowish-brown material which occurs at lower depths and is saturated with water.

96–102 inches; woody peat, dark brown in color and consisting of flat-rooted stumps of a mixture of hemlock, "cedar," spruce, and pine, well disintegrated crumbly granular material, needles, cones, bark, fallen timber and coarse woody fragments which show the decomposing action of air and micro-organisms; the layer is derived from a coniferous swamp forest that reached its development on shallow peat under conditions favorable to tree growth.

102–120 inches; sedge peat, brown, felty fibered, somewhat compacted and partially decomposed; the material is grayish brown and sandy at the lower level; it contains seeds of buck bean (*Menyanthes trifoliata*), collodial organic residue, herbaceous plant remains, and roots and rhizomes which extend into the underlying mineral substratum.

120+ inches; gray to bluish-gray sandy and clayey gravel.

This record shows that peat formation has been continuous in all probability since the retreat of the local glaciers; that sedge peat of good quality accumulated in considerable thickness, absorbing water, retarding its runoff, and storing it to the point of saturation; that a change of water level intervened twice during the formation of a woody peat composed largely of material from two conifer forests; that the stand of timber in the older forest at the lower level was fairly dense and consisted of a mixture of hemlock, pine, "cedar," and spruce, while the succeeding forest near the 4-foot level above the glacial till was of slow and open growth and in small patches, hemlock being less abundant; that the present type of timber at the surface is mainly lodgepole pine, stunted, slow growing and widely scattered; and that sphagnum mosses have appeared only relatively recently in muskegs, as a readjustment consequent to poorer nutritional conditions that did not exist in these localities during the accumulation of sedge peat and woody peat below the surface near the base. These interesting relationships serve to illustrate how slope muskegs represent successions of several peat-forming types of vegetation superimposed upon one another.

It is relatively easy to segregate the structural features into layers of peat formed by sedge marshes, swamp forests, and sphagnum moss bogs, but a classification of muskegs cannot be based on the assumption that the present surface vegetation and the texture and other characteristics or properties of the peat material just below the surface express significant differences. They assist in the understanding and correlation of the facts necessary for a comprehensive view. It is important to recognize clearly that a serious study of the complex of factors and correlations has hardly begun. It is clear that classification and use capabilities of muskegs must be worked out on a different basis. The problem must be approached not merely from a descriptive point of view but also from that of history and particularly of former environmental conditions of peat-forming vegetation.

MITKOF HIGHWAY (NO. 9)

It is interesting to note that exposed cuts and soundings made in muskegs along the Mitkof highway, about 11 miles southeast of Petersburg, show profile characteristics that are essentially alike to the slope muskegs discussed above and to those in localities south of this district. The convexity of the local muskegs is due mainly to the form of the underlying mineral substratum. The surface vegetation is quite similar except that aquatic species of sphagnum mosses are relatively abundant in pools of water. Typical forms are *Spaghnum cuspidatum* and *S. squarrosum*, the former dominant also in wet depressions between hummocks. The more conspicuous hummock formers are *S. fuscum*, *S. rubrum*, *S. medium* and *S. papillosum*. They accumulated in places a thickness of 20 inches of moss peat, grading into a yellow-brown fibrous sedge peat below the second foot level. The structural features of a typical cross section include felty-fibered, more or less laminated sedge peat, brown, with a reaction of pH 5.0, and two separate layers of woody peat containing flat-based roots, stumps, and fallen timber derived from conifers. At the base is a sandy sedge peat, and the mineral substratum near the 9-foot level consists of sandy gravel overlaying bluish-green fine sand and silty clay.

KUPREANOF ISLAND

Kupreanof Island is separated from Mitkof Island by a narrow tidewater passage. On the north end of the island are small mountain ranges of which the one near Kake village has summits reaching altitudes of 3,000 feet, while the other just west of Portage Bay includes peaks 2,500 feet in elevation. A low pass from Portage Bay to the head of Duncan Canal separates the eastern from the western half of the island.

LINDENBERG (NO. 10)

The section between Duncan Canal and Wrangell Narrows nearest Petersburg is densely wooded with hemlock and spruce. An exception are the muskegs situated on the Lindenberg Peninsula in the low pass between the tidal waters. The border of the muskegs has scattered lodgepole pine but there does not seem to be any evidence that trees were killed by fire. The muskegs extend for a distance of about 3 miles on a slope of moderate grade. Sedges, including *Scirpus caespitosus* and species of *Juncus*, *Carex*, a few cottongrass, reindeer moss lichens (*Cladonia rangiferina* and others) and *Empetrum nigrum*, *Kalmia polifolia* and several species of *Vaccinium*, are the characteristic vegetative cover of this area. Sphagnum mosses are not dominant; they occur in small hummocks on which are found also *Drosera rotundifolia*, *Rubus chamaemorus*, *Cornus canadensis*, *Pinguicula* sp., *Lycopodium* sp., and a few ferns. There are numerous small shallow pools of water at different elevations, varying in size and turbidity; some contain yellow water lily, others support *Menyanthes trifoliata* or pond weeds; the water is pH 5.0 in reaction and shows no evidence of drainage. An interesting feature is funnel-shaped depressions resembling those mentioned by Auer (*1*) in his report on Canadian peat areas. They are found rarely in the peat depsoits of continental United States. The funnel examined in this muskeg has a broad upper and a narrower lower conical form of irregular shape. Its position is on the side of a sloping channel. The exposed profile section shows no disturbance except that the peat material in the depression is somewhat more decomposed than that of newly cut sections. There appears to be no subterranean channel since the water level stands 4 to 5 feet below the surface. It seems probable that the funnel is the result of water flowing from thawing snow and ice, or heavy rains eroding peat material that is considerably looser in texture than elsewhere.

Profile samples were taken at 1-foot intervals from the surface to the bottom in several muskegs located on the slope. They ranged in depth from 6½ to 10 feet but the deeper ones appeared to be more waterlogged. The vertical sections show the following changes to have taken place during the formation of the peat deposits:

0–3½ feet; sedge peat: the upper 10 inches consist of dark-brown partly decomposed fibrous sedge peat having a reaction of pH 5.0; embedded in it are varying amounts of light yellow-brown sphagnum moss peat, woody roots from heaths and scrubby pine, roots and rhizomes of the growing sedge-grass vegetation; the material below is reddish-brown fibrous-matted sedge peat and relatively free from woody fragments; it accumulated under conditions when trees could not establish themselves.

3½–4 feet; woody peat with stumps and flat roots overlying dark brown, crumbly, moderately decomposed sedge peat.

4–5½ feet; sedge peat; brown, felty fibered, acid in reaction, with occasional woody roots from shrubs and bits of deciduous leaves.

5½–6 feet; woody peat, very dark brown in color; contains well decomposed organic residue which is granular but more or less plastic; stumps occur at the lower level.

6–7½ feet; sedge peat, yellowish brown, fibrous, grading into dark-gray sandy sedge peat.

7½ feet; gray sandy gravel, giving a reaction of pH 5.5 to 6.0.

PORTAGE BAY (NO. 11)

Similar profile sections were noted at Portage Bay in a muskeg located about half a mile southeast of the bay on the trail to Petersburg Lake. The Portage Bay muskeg is five-layered and its depth is 8½ feet at the deepest place. The profile consists of sedge peat and two layers of woody peat at the 5- and 7-foot levels respectively. It is to be noted, however, that the sedge peat below the 3-foot and 7½-foot levels contains an admixture of well preserved light yellow brown plant remains from *Hypnum* mosses. The underlying mineral substratum is a gray tinted sandy gravel.

KAKE (NO. 12)

The muskegs back of the cannery and the first and second dam at Kake are less accessible and less typical. They vary in thickness of layers and in depth to the mineral substratum. The upper portion of the sedge peat contains small amounts of moss peat but many woody roots and shoots from heaths; much of the material below the surface is waterlogged and contains timber which make it difficult to obtain profile samples.

HAMILTON BAY (NO. 13)

At Hamilton Bay on Kupreanof Island a muskeg occurs on the south shore at a point about 2 miles east of Point Hamilton. It is located close to the beach and surrounded in places by an outctop of conglomerate Tertiary rock. Profile soundings indicate that the layers of peat accumulated in a local basinlike depression. Depths to the mineral substratum range from 2 and 6 feet near the margin to 11 and 14 feet in the deeper parts of the peat area. Scattered stunted pine and a complex of low heaths modify somewhat the appearance of convexity which is evident in the central section when observed from the floor of the helmock and spruce forest around the muskeg. The topography of the surface and that of the underlying mineral substratum on which the muskeg developed, have not been determined with surveyor's instruments; hence it is difficult to state whether the area represents a raised or a flat type of muskeg.

Sphagnum mosses have formed large and firm hummocks in which grow sundew, low cranberry, Canadian dogwood and *Empetrum nigrum*. In places of that kind the living sphagnum mosses can readily be collected with rakes or other picking devices and the cleared areas, when properly cared for, should be used to propagate the mosses for future harvests.

The vertical profile structure of the Hamilton Bay muskeg is relatively simple and shows the following features in the deeper sections of the area:

0–20 inches; moss peat; yellowish to reddish-brown, spongy, varying in thickness from 12 to 15 inches and grading into a reddish brown slightly decomposed moss peat which is strongly acid at the lower level.

20–125 inches; sedge peat; the upper portion consists of a mixture of moss and sedge peat, is waterlogged, and contains a few woody roots of shrubs; the material at the 30-inch level is brown, fibrous, matted and rather firm; near the 70-inch level occurs an admixture of woody fragments in brown partly decomposed sedge peat; the material from the 82-inch to the 96-inch level includes yellowish-brown well-preserved plant remains from *Hypnum* mosses; it grades into a brown firm felty-fibered sedge peat, which is sandy underneath the 120-inch level.

125–130 inches; sandy gravel over bluish-tinted silty clay.

MUSKEGS OF THE JUNEAU DISTRICT

In common with most of southeastern Alaska, the part of the mainland on which Juneau is situated and the adjacent Douglas and Admiralty Islands are a portion of the rugged mountain mass that had been heavily glaciated. The islands have no glaciers at the present time but several glaciers still remain on the mainland north and east of Juneau, among them Mendenhall Glacier, Lemon Creek Glacier, and Norris Glacier. Mountain crests within 3 or 4 miles of the coast stand 3,000 feet above sea level, and a few rise to an altitude of more than 4,000 feet (*22*). A dense forest growth covers the mountain slopes to an altitude of about 1,700 feet and shelters a variety of muskegs, lakes, ponds, and wildlife.

There are large salmon canneries on the nearby shores, and fur-bearing animals are raised there and on a number of islands leased from the Forest Service.

Agriculture is entirely for local needs and consists of dairying and growing garden vegetables and small fruit.

DOUGLAS ISLAND SKI TRAIL (NO. 14)

On the slopes of Douglas Island, which is separated from the mainland by Gastineau Channel, the muskegs are of a character somewhat different from the types that cover the general surface of the country around Juneau. The island is forested with hemlock and spruce which extend up to altitudes of approximately 2,000 feet. An undergrowth of blueberry brush (*Vaccinium* sp.), devilsclub (*Oplopanax horridus*), skunkcabbage (*Lysichiton camtschatcense*), elder (*Sambucus leiosperma*), *Menziesia ferruginea*, ferns, and others are prevailing features of the forest. Isolated lodgepole pine, small and stunted, are characteristic of the open moss-sedge muskegs which are too wet for other conifers. In transition zones which are usually found about the margins, the forest trees are scrubby and ericaceous shrubs are dense.

The mineral soils of the better type of forest near the shore of Douglas Island are characterized by the presence of a thick needle and leafy litter which is poorly decomposed for the first 4 to 5 inches; the second horizon of 2 or 3 inches is dark brown and more or less granular, well decomposed organic residue with woody fragments; it is sharply demarked from a gray leached coarse sandy clay about 5 to 6 inches thick; below that is dark rusty-colored sand, presumably stained by iron and in places rather cemented; it shades into light-red sand and gravel which merges with a gray coarse sandy gravel at a depth of 2 feet or more below the surface.

At a point opposite Juneau, a ski trail renders several muskegs accessible as far up the slope as the pipe line which carries water to the town below. Beyond that point the trail is indistinct and the muskegs which cover the higher slopes were not examined. However, essentially the same general character of vegetation forms the basis of all the local slope muskegs. They have an abundant growth of sedges, patches of sphagnum mosses, and mixed communities of low shrubs usually consisting of several species of heaths. Sphagnum mosses do not form a continuous cover and the accumulation of moss peat occurs only in occasional hummocks.

Soil-profile development in the muskegs is so marked in its infancy that no appreciable differentiation into horizons can be observed. Peat accumulation is continuous, the water table is generally at or near the surface, shallow pools of water are common, and the pH value ranges between 5 and 5.5. The annual addition of plant remains from the low-growing herbaceous vegetation, already mentioned elsewhere in this report, merges into a yellow-brown fibrous mixture derived from roots and rhizomes of sedges with material from sphagnum mosses and heaths. The decomposition of the plant remains is greatly retarded owing to the lack of aeration, soluble salts, and the activity of microorganisms. Woody shoots and roots from heaths and pine have their best development at a depth of about 10 inches below the surface. From the second to the fifth foot level the organic material consists of reddish-brown, fibrous, matted sedge peat which merges into the underlying brownish-gray sand, containing root channels. Below it, the mineral material is gray, bluish-tinted, sandy gravel to 5½ feet from the surface.

Bedrock exposed on the island is a slate and graywacke with some greenstone (*21*). Influences associated with frozen subsoils or wind and volcanic action have not been observed in the profile sections and are not known to exist in this region.

JUNEAU MAINLAND

This section of the district consists of a narrow strip of country lying between Gastineau Channel and the high peaks of the Coastal Range. It is composed of ridges with a northwest trend parallel to the coast, and rising more or less steeply from the water's edge. Forest of spruce and hemlock grow in protected localities, in valley bottoms, and up to altitudes of nearly 3,000 feet. Muskegs occur mainly on the glacial till which covers the bedrock of the region; they are found at a number of localities along the coast but are believed to have a much wider distribution inland.

GASTINEAU CHANNEL (NO. 15)

On the highway from Juneau to Mendenhall Glacier a cut which was made in constructing the roadbed, exposes the portion of a muskeg at a point approximately 7.2 miles northeast of town. Rigg (*33*) has listed its vegetation cover and describes the general character of the peat area as a raised moor which developed in a saucer-shaped depression and consists of three layers of peat—sedge, wood, and sphagnum.

At the time the area was examined by the writer (June 1939) a spur road, leading at mile 7 from Glacier Highway to Gastineau Channel exposed a fresh cut of the muskeg which revealed the entire profile (fig. 7). Soundings made along the north side of the peat area on Glacier Highway correlated with the profile features of the eastern portion where the raised muskeg extends toward the beach. The two cross sections show that the muskeg developed on a flat which at present has an elevation less than 7 feet above mean high water, and that a portion of the flat appears to have been covered at one time by

FIGURE 7.—A fresh cut of the raised muskeg enclosed by a forest on Gastineau Channel near Juneau.

the tidal waters of Gastineau Channel at least several feet higher than the present sea level. The evidence consists in a variety of large marine shells from bivalves which were buried when sedge peat began to accumulate. The profile section displays also the remains of old forests at two levels, the lower one 3 feet above the mineral substratum, the upper about 2 feet higher. The woody peat at the lower level is dark brown in color and contains well decomposed granular organic residue as well as needles and woody material from conifers; the stumps in it vary in size and are a mixture of hemlock and spruce. The woody peat of the middle layer is less well decomposed and in places charred, indicating the existence of drought and fires at that time.

Figure 8 records the sequence of a good quality of moss and sedge peat layers and the stumps of the buried middle forest in the upper portion of the cut exposed on Glacier Highway above mile 7. The material at the surface is reddish-brown, spongy, sphagnum moss peat of good quality; it represents a growth of hummock-forming mosses and contains none of the woody components, fibers of cottongrass, or seams of decomposed plant remains that characterize wet depressions. In other vertical sections the moss peat represents a more complex development; it varies in thickness from 3½ to 5 feet and merges below the 5-foot level into a mixture of sedge and moss peat, yellow to reddish-brown in color. The fibrous material between the two forests

FIGURE 8.—Photograph of profile section of the muskeg exposed near Juneau, showing roots of spruce and fallen timber of the middle forest on sedge peat and buried by a subsequent accumulation of sphagnum moss peat.

consists of gray-brown, felty-fibered sedge peat while that near the bottom of the muskeg grades into sandy sedge peat with iron-stained root channels. It merges with a bluish-gray sandy clay, firm and mildly alkaline in reaction (pH 7.5). A tough glacial till, obviously derived from a former tributary of Lemon Creek Glacier, covers the bedrock of this region, and marine fossils are found at a number of localities. Marine shells have been reported by Knopf (*22*) and are believed to have a much wider distribution inland, although generally concealed under peat.

There are several reasons for giving this muskeg a unique value. A feature of great interest is the fact that the period when the shore of Gastineau Channel was free from ice and subsequent high tidal water was brought to a close by an advance of vegetation. Parts of the channel shore undoubtedly became forested from the timber line to the water's edge. As in the forest of today, the tree species were hemlock (*Tsuga heterophylla, T. mertensiana*) and Sitka spruce. But the superimposed ancient forests that grew at two levels on sedge peat and replaced the original sedge marsh may possibly indicate a general change in drainage or climatic conditions, or both. It is probable that the local ice movement included a number of advances and retreats. During a retreat, conditions favored decomposition of sedge peat at the surface and permitted for a time the invasion and growth of conifers. The timber was in turn buried beneath a layer of sedge and finally by moss peat, which accumulated during the later course of events that terminated the successional development of the previous major groups of vegetation.

In this connection the interesting question suggests itself, whether the ancient forests buried in the muskegs of this district and elsewhere in Alaska are contemporaneous with the interglacial forests reported by Cooper (7) at two levels in the morainal gravels of localities recently uncovered by the recession of glaciers in Glacier Bay. It is quite possible that the advance of ice which built up the gravels at Glacier Bay, and the temporary recession of the ice during which the superimposed forests came into existence in muskegs, represent recent stages that can be correlated. The development is measurable and may not vary considerably in age, but must await further evidence for solution (p. 32).

HERBERT RIVER (NO. 16)

In the gravel-floored valley of Herbert River, which like Eagle and Mendenhall Rivers is of glacial origin, several muskegs occupy extensive flats. They support dense growths of cottongrass and buck bean, as well as quaking mats composed of sphagnum and hypnum mosses with sedges in the low and wet places, also isolated groves of dwarfed spruce and heaths (fig. 9). Willow-alder thickets with an undergrowth of ferns, iris, orchids, lupine, and other herbs occur on the intervening sandy ridges. From these ridges the less favorable areas have been and still are being invaded by a preliminary extension of alder thickets in certain places, and directly by spruce, pine, and heaths in others.

That cottongrass has been active in the formation of peat, and that the quaking-mat stage has been of fairly longer duration than the thickets and conifer stage, is apparent in the comparative thickness of vertical profile sections. From the surface to a depth of 6 feet the material consists of a yellowish-brown, coarsely fibrous and matted network of rootlets and rhizomes from sedges in which are embedded the leafy stems of sphagnum and hypnum mosses. The layer is appreciably looser on the downstream side of the valley and less acid in reaction (pH 5.5) than elsewhere. The underlying mineral substratum is gray sandy gravel.

The advance of sphagnum mosses, heaths, and conifers has taken place in this region more rapidly west of the valleys along the coast. Between Favorite Channel and the mountainous background, particularly near Auke Bay and Pearl Harbor are flat muskegs from which samples of peat were collected in the hope of obtaining further evidence bearing on the recent origin of sphagnum moss peat. Examination of the material indicates clearly that layers of moss peat do not occur in the lower bulk of the peat when muskegs begin to develop. In the river valleys ground water is the most effective control of the growth and composition of marshy vegetation and the character of peat layers formed by them. Farther west and near the coast, rainfall and humidity are of most importance in promoting the spread of sphagnum mosses and in determining the nature of the peat material and the structure of the muskeg.

LOOP ROAD (NO. 17)

Near the junction of Loop Road with Glacier Highway at mile 12.8, a cut was made in a muskeg situated along the road about 150

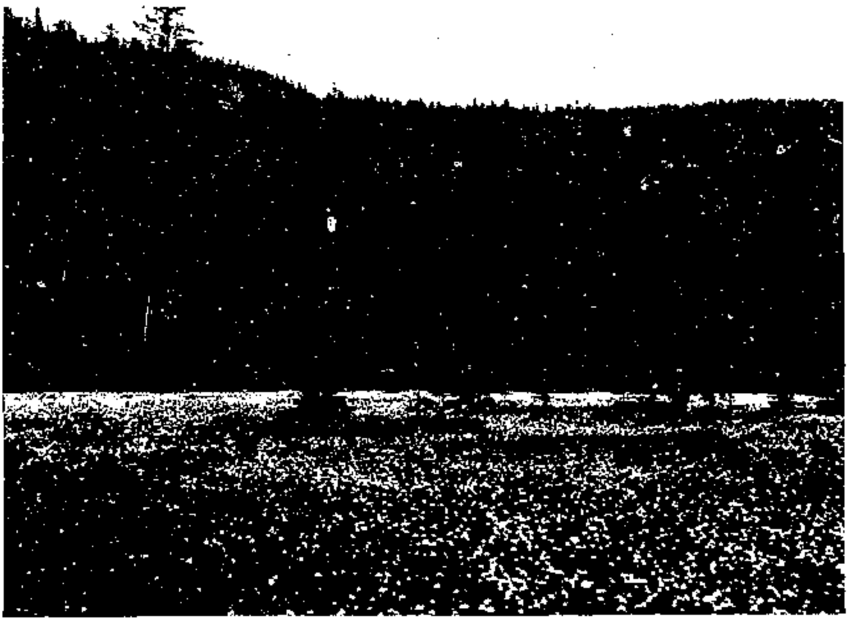

FIGURE 9.—Dense growth of cottongrass (*Eriophorum* sp.) forming a quaking mat which is the first stage in the development of muskegs on the gravel-floored valley of Herbert River at mile 26 of Glacier Highway near Juneau, Alaska.

feet from the Auke Bay store. There has been considerable disturbance in the natural conditions of the peat deposit but the vertical profile section exposed on the west side of the road reveals a surface layer of brown sphagnum moss peat of varying thickness which has not contributed as yet to the development of a convex, dome-shaped surface. Below the 16-inch level is a complex of moderately decomposed granular material with woody roots and stumps of the growing trees and shrubs.

The underlying sedge peat is felty fibered and reflects in its character very little variation in decomposition and consequently little change in wet conditions. At a depth of about 4 feet below the surface occur stumps and charred woody peat indicating former drier conditions and the effects of fire. In the basal part, toward the 7-foot level and the underlying glacial till, the alternating layers of sedge peat and woody peat are evidence that the development and stratigraphic features of the muskegs of the whole district took place in the same order and are synchronous.

MONTANA CREEK (NO. 18)

The narrow valleys of Montana, Windfall, and Cowee Creeks, extending parallel to the coast northwestward of Juneau to Berner's Bay, are forested with hemlock and spruce but diversified by muskegs. The peaty areas are located usually on the flats or benches and support a covering of sphagnum mosses with a dwarfed open growth of heaths and lodgepole pine. The muskeg at Montana Creek is approximately 16 miles from Juneau, larger, and more easily accessible for economic development than any of the other peat areas examined in this strip of territory. The recent construction of a government highway up the main valley of Montana Creek passes through this deposit and connects it with Juneau.

A study of the growing vegetation, though leaving much to be desired for completeness, shows that sphagnum mosses are in the main the really effective peat formers. The surface of the raised portion of the muskeg is not uniform but consists of alternating hummocks and hollows inhabitated by different species raising the level of the water table as the plants grow upward. Of the sphagnum mosses inhabiting drier situations, the most prevalent are *Sphagnum acutifolium*, *S. fuscum*, *S. rubrum*, *S. medium*, *S. papillosum*, the latter species contributing to the progressive development on the side east of the road. The surface is dome shaped and has the appearance of a raised muskeg. Stagnant pools of water and secondary small lakes of irregular pattern caused by various modes of origin, occur in several places; some are bordered with sphagnum mosses (*Sphagnum cuspidatum*) but aquatics such as *Potamogeton* sp., *Myriophyllum* sp., *Caltha palustris*, *Utricularia vulgaris*, and *Nymphaea polysepala* are rare. The wet portions of the muskeg support a few clumps of sedges (*Carex pauciflora*, *C. limosa*, *C. spectabilis*, *Eriopohorum chamissonis*) some grasses (*Calamagrostis scabra*), and various herbs such as *Hippuris vulgaris*, *Nephrophyllidium crista-galli*, and *Galium trifidum*, but these are the least important as contributors to the formation of peat. Individual scrubby mountain hemlocks grow in fan-shaped form on the wetter sites of the muskeg.

From the soundings and samples of profile sections examined, the Montana Creek muskeg gives evidence of having been originally a sedge marsh which later supported some timber but was soon replaced by sphagnum mosses. The arrangement of its layers is practically the same as may be seen exposed on the flat near Gastineau Channel, except that the layer of woody peat from the second superposed forest is not well developed. The surface layer of moss peat is relatively thick and exceeds in extent and amount the moss peat in the Gastineau muskeg near Juneau. The character and distribution of peat layers are indicated in the following generalized profile section.

0–9 feet; sphagnum moss peat; the surface is spongy, well preserved, typically reddish-brown, fairly compact and pH 4.0 in reaction; there are present vertically elongated components of fibrous material from mosses, cottongrass and other sedges and several thin, sharply defined seams of dark brown and more decomposed moss peat which represent material that was formed in shallow pools of water; the layer is moist below the 2-foot level and contains methane gas.

9–17 feet; moss peat with an admixture of plant remains, roots and rhizomes from cottongrass and sedges; the material is matted fibrous, generally free from colloidal organic residue, brown in color with a yellowish tint; at the 15-foot level it is moderately decomposed and contains some woody fragments but no development of a woody layer of peat; below it occurs *Hypnum* moss peat, yellowish brown in color, turning to a very dark brown upon exposure to the air.

17–20 feet; sedge peat, grayish brown, partly fibrous, composed of fine roots and flat underground stems of sedges which appear to have spread over shallow water; it contains woody fragments from shrubs and timber and granular matter representing the remains of a tree growing vegetation transitional in character; at the lower level the sedge peat contacts with the underlying mineral substratum.

20 feet, gray fine micaceous sand on sandy gravel.

Around the margins of the convex portion of the muskeg the material consists of sedge and moss peat which is considerably fibrous and more or less woody.

Peat resources of the raised muskeg type have not received due recognition. The Montana Creek muskeg is well suited for the manufacture of peat products.

Its drainage will depend in part on the lay-out of the manufacturing plant but should be carried out gradually.

LENA BEACH (NO. 19)

In the vicinity of Lena Beach and Glacier Highway at mile 17.5-the muskeg cut by the road represents less advanced conditions in the spread of sphagnum mosses. The general surface is dome shaped, and thinly covered with stunted conifers. Hummocks of sphagnum mosses are common. Among the herbs are species of *Drosera*, *Rubus*, *Maianthemum*, *Lycopodium*, *Cornus canadensis*, *Oxycoccus microcarpus*, fruticose lichens of the reindeer moss type, and others. The shrubs include species of *Vaccinium*, *Ledum*, *Andromeda*, and *Empetrum nigrum*. The depth from the convex surface elevations on the west side of the road to the underlying mineral substratum is 14 feet. The structural profile features of the muskeg and the possible changes in general environmental conditions that may have affected the region during the period of peat accumulation can be stated as follows:

0–3½ feet; sphagnum moss peat, brown, yellowish tinted with thin seams of darker colored material due to local variations in pockets of water and shallow pools and in uneven decay caused by hyphae of certain lichens and algae.

3½–8 feet; moss peat with an admixture of roots and rhizomes from sedges, relatively well preserved; this material and the layer above it, support the view that accumulation took place during a comparatively cool and moist period.

8–10½ feet; brown fibrous sedge peat, felty fibered in texture; the raw nature of the material seems to indicate a moist but relatively warm period and high ground-water levels which favored an increase in the quantity of root and rhizome development.

10½–11¾ feet; woody peat, dark brown in color characterized by stumps of conifers which advanced over the peat area during a relatively dry and warm period.

11¾–13½; brown fibrous sedge peat which contains organic sediments formed in shallow bodies of water and plant remains from Hypnum mosses in a well preserved condition; the appearance of the material suggests a high water table and a moist period which was possibly cool.

13½–14 feet; dark-brown woody peat with stumps of conifers in a well decomposed black granular residue which is silty at the lower level and grades into a dark-gray fine sand and gravel.

Judging by the character of the peat layers, the period during which the woody peat accumulated was probably warm and dry, the area relatively well drained, and the timber in the earlier time of a better growth than that of the plant cover of today. Sphagnum mosses, on the other hand, did not appear and did not begin to spread until relatively recently.

In view of the essentially identical sequence and character of layers in the muskegs of southeastern Alaska, it seems possible that a method is available to determine whether the alternating drier and wetter conditions were synchronous over a wide stretch of country, and whether the ancient forests exposed at two levels in the gravel bluff near Muir Glacier at Glacier Bay give evidence of changes in climatic conditions and may be correlated with the two superposed forests that originated probably at corresponding periods in the muskegs. It is more than probable that the environmental conditions described above may be correlated with those that affected Europe in post-glacial time. In that case the early dry warm period when forests spread over drying sedge peat would correspond with the Boreal period; the following moist and probably warm period, which encouraged the development of sedge marshes, with the Atlantic period; the next dry warm period and its invasion and spread of forests, with the Subboreal period; and the last moist and cool period marked by the spread of sedges and sphagnum mosses, with the Subatlantic period. In the present period forests are again invading muskegs.

In geological and ecological literature (*5, 7*) there are frequent suggestions that the glaciers in the northern hemisphere are receding and that vegetation may be undergoing the readjustments consequent upon the restriction of glaciation in Alaska to mountainous areas and of arctic conditions to polar regions. The gradual spread of conifers into muskegs, and the advance of the timber line northward, described by different writers (*7, 19, 24*), justifies the conclusion that the present time is possibly a stage approximating the warmer and drier conditions which existed at earlier intervals.

PEAT RESOURCES IN SOUTH-CENTRAL ALASKA

South-central Alaska includes islands and the central portion of high mountain ranges which encircle Prince William Sound and resemble southeastern Alaska in physiography, climate, and vegetation; and also the adjacent large watersheds which extend inland to central Alaska.

The Chugach National Forest is the timber belt along the coast and on the right-of-way of the Alaska Railroad between the towns of Seward and Anchorage. Grant and Higgins (*18*) described the topographic features of the coast as rocky and precipitous, with elevations from 2,000 to 5,000 feet, rising rapidly to the summit of the Chugach Mountains, which reach altitudes of over 10,000 feet. Most of the higher valleys are occupied by glaciers many of which extend down to sea level. The shore line is broken by a succession of bays, inlets, and arms of the Sound, washed by the warm waters of the Pacific. Spruce, hemlock, and a small amount of "cedar" are the prevailing forest growth, and the very sinuous coast line makes much of the timber as well as many muskegs accessible. There are considerable deposits of unmodified and well-sorted glacial material, the latter frequently varied, and much of the sand, gravel, and silt in the broader valley flats has been spread out by streams flowing from the melting glaciers. The prevailing rock formation is slate and graywacke with only a thin covering of soil on rock outcrops. Fishing is the chief means of community support, centering around Valdez, at the head of Port Valdez, and Cordova, on the east shore of Orca Inlet.

The level and rolling lands that occur inland in the valleys have a light forest cover and a climate not unlike that found in the northern tier of Prairie States. Precipitation is moderate and the summer seasons are short but rather warm. The Matanuska agricultural area is located in one of these valleys in the vicinity of Anchorage. Vegetables, root crops, and hay are the principal products supplied to mining and other communities along the Alaska Railroad.

The region has two important gateways into the interior of Alaska—the federally owned and operated Alaska Railroad, which extends from Seward to Fairbanks; and the Richardson Highway, which leads inland from Valdez to Fairbanks and, by way of the Steese Highway to Circle on the Yukon River. Formerly, a railroad connected tidewater at Cordova with the mines on the headwaters of the Copper River drainage area, but now the road is no longer in service.

MUSKEGS OF THE CORDOVA DISTRICT

The Cordova district comprises the easternmost area of Prince William Sound between Port Valdez and the Copper River. It has much the same climate as that of the southern coast but its topographic features are varied in places by lowlands, small lakes, hills, and groups of rugged mountains. The principal valleys are of glacial form with deposits brought to their present position chiefly through the agency of glacial ice and water.

The most extensive embayment along this portion of the coast is formed by the Copper River delta, a broad gravel and silt-floored lowland with shoal waters which extend for some distance seaward. Nearly all of the tributaries of the river head in glaciers and carry heavy deposits of glacial silt, sand, and gravel during flood stages in summer. The lowlands are in part timbered with spruce and hemlock extending to an altitude of about 3,000 feet, but on some of the islands in the river and adjacent flats the growth consists of cottonwood together with some white birch, spruce, and marshy muskegs. The track of the abandoned Copper River Northwestern Railroad crosses the delta, making it possible to examine peat-covered areas in a number of localities.

COPPER RIVER (NO. 20)

The lower course of the Copper River differs in topographical features from deltas generally found elsewhere. There are many shifting and anastomozing branches of the river, bars, and dune-shaped hillocks seldom more than 15 or 25 feet high, and shallow basins of varying size in which occur ponds, marshes, and transitions to muskegs. None of the peat-forming areas are of any depth and most of them may be described as flat, lying on sandy silt and gravel far enough from the seashore no longer to be reached by tidewater. They are of particular interest, however, for an understanding of any essential differences between the origin of muskegs formed in earlier periods and those that are developing at the present time.

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The distribution of peat-covered areas is not indicated on any topographical or geological maps of the district and for this reason any account of their location must necessarily be approximate. A number of them have been examined along the railroad, but owing to the scarcity of place names they are indicated below by the nearest milepost and described in terms of developmental changes. In this case it is also very important to have an account of the origin of muskegs based on accurate knowledge of the nature and quality of the basal layers of peat.

At mileposts 22, 28, and 34 east of Cordova occur bodies of shallow open water which support chiefly buck bean. The accompanying plants, in order of their abundance, are species of *Equisetum* and *Carex* together with *Potentilla palustris*. The general aquatic vegeta-

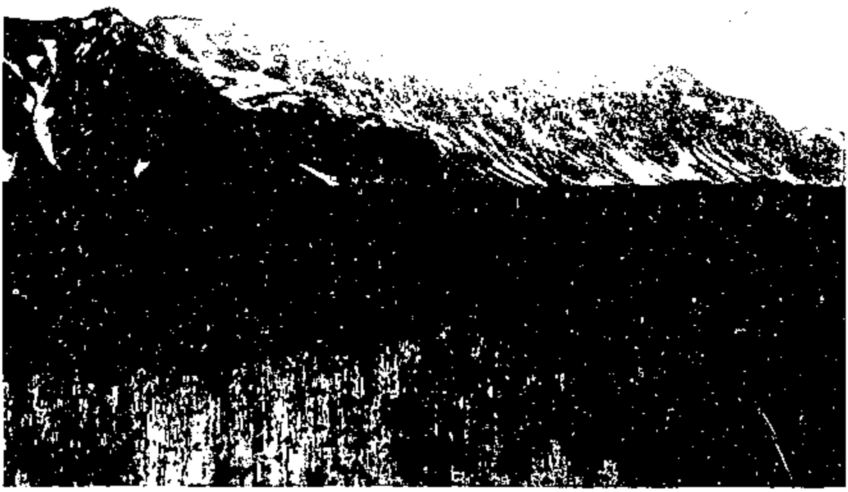

FIGURE 10.—A pure stand of buck bean (*Menyanthes trifoliata*), a second stage in muskeg development, occupying shallow water in the flats of Copper River, Alaska.

tion of the ponds is not prolific when compared with similar habitats further south; there is a scarcity of algae and of free-floating or submerged pondweeds and other plant life. The closely standing plants are anchored with rootstocks which spread over firm sandy silt (fig. 10) and give rise to a coarse-fibered and matted network of roots and rhizomes in water standing knee deep. The reaction of the water and the organic material is around pH 7.0. The margins are frequently bordered by a narrow zone of sedges, followed by various species of willow and alder thickets.

Between mileposts 7 and 19 occur several well-defined sedge marshes (fig. 11). The vegetation consists of *Carex lyngbyei*, *C. aquatilis*, and *C. stricta* with a lesser amount of *Eleocharis palustris*, *Menyanthes trifoliata*, and species of *Juncus*, *Scirpus*, *Eriophorum*, and *Equisetum*. The water level is at or slightly above the surface, and soundings which were made at various places indicate approximately 18 inches of fibrous sedge peat; the material is yellowish-brown with a grayish tint from the admixture of silt; it contains rhizomes of buck bean at the lower level and several thin seams of fine sand; the underlying mineral substratum is firm fine sand containing gravel. The reaction of the organic matter is only slightly acid, varying between pH 6.0 and 6.5. The contrast of this form of vegetation, and the work accomplished by it, is very striking when compared with contiguous bodies of water which are only beginning to be colonized by buck bean and sedges, and with the older sedge marshes in nearly pure stands which transformed the sandy flats into peat-covered areas.

Similar marshes occur near mileposts 24, 25, 35, and 37, but they show patches of scrubby willow and alder, cottonwood, and a scattered

FIGURE 11.—Streamway of Copper River, Alaska, showing typical sedge marsh, a third stage of development, occupying an area which was formerly colonized by buck bean.

growth of small spruce trees similar to those frequently found on muskegs.

Landward from the shifting braided channels of the overloaded river, and especially on sandy gravel banks along the streams, where the flats are better drained, the sedge marshes give way to a series of thickets and riverbank poplar forest. Bush willows and alder with ferns, elderberry, and spirea come in and are increasingly luxuriant where the sedges give way to grasses, such as *Calamagrostis*, and the poplars. Extensive poplar forests occupy some of the broad flats and older dunes between mileposts 38 and 40; among the conspicuous trees are tall Balm-of-Gilead with northern black cottonwood (*Populus trichocarpa hastata*) and alders in the openings. Soundings made in the poplar swamp forest gave cross sections with the following profile features:

0–22 inches; the upper 3 to 4 inches consist of brown leafy litter and other plant remains accumulating continually and interwoven by loosely matted grass roots; the lower 8 to 9 inches consist of dark reddish brown more or less decomposed organic material in which grass roots are less abundant and the woody roots of poplar and alder are relatively more numerous. In the second foot level the peat material is reddish brown, partly fibrous sedge peat, a bit silty from previous overflows, shading into a yellowish-brown sandy sedge peat in which are seeds and rhizomes of buck bean and the sedges that originally occupied the flat of gray sand and gravel.

In wetter places the poplars are gnarled and stunted, protruding through tussocky sedges, so-called nigger-heads, and isolated patches of scrubby willow and alder, characteristics of the competition and vigorous conditions of their habitat. The plant cover takes on a hummocky surface with intervening hollows which vary in size and depth. On the ridges occur several small heaths, mainly species of *Vaccinium*, but sphagnum mosses, reindeer mosses, and lichens are of very subordinate importance. The composition of the community is quite indefinite, shading into neighboring transition types of vegetation. Nowhere in the Copper River district are heaths, conifers, or sphagnum mosses abundant enough to justify the application of the term muskeg to the peat-forming areas that are now developing in the delta along the Copper River railroad. The present types are still transitional stages of vegetation; they are essentially like those that formed the bottom layers of muskegs at earlier periods and they are characteristic of the effects of ground waters and their supply of mineral plant-food constituents. The importance of atmospheric water is not evident in those vegetation types; they have not reached the climatic limit of the rainy and cloudy coastal environment but are the forerunners of muskegs. By far the most important factor in the development of muskegs over the top of marshes appears to be precipitation water. Where muskegs have succeeded marshes localized in a basin, they are for a time restricted to the basin, until the upward accumulation of plant remains has raised the water level above the neutral or alkaline ground water.

CHITINA (NO. 21)

The upper Copper River Basin is a broad plateaulike country, deeply dissected near its margin and varied in places by hills, groups of mountains, and many small lakes and muskegs. A reconnaissance soil survey of a part of this region has been published by Bennett and Rice (*3*). The region has an entirely different condition of atmospheric humidity and of winter cold from Cordova and the seaward side of the mountains.

In the town of Chitina a cut was made in the construction of the Copper River and Northwestern railroad which leads to the bridge where Copper River is joined by Chitina River, its largest tributary. A typical section exposes solid rock and glacial till in a depression that probably dates to the time of a glacier's retreat at that place.

At the base of the cut is 65 feet of unconsolidated gravel and sand with an even, concave surface which consists of 6 feet of fine sand. Above the sand and extending to the top of the cut is 15 feet of more or less woody peat showing about four to five layers of flat-rooted stumps of spruce superimposed upon one another. Throughout the deposit, the peat material contains a large quantity of wind-blown silt and small shells of univalves, picked up doubtless by prevailing winds from the beds of Copper and Chitina rivers. The surface vegetation of the deposit, back from the cut, consists of shrubby willows and *Potentilla fruticosa* in a ground cover of various sedges, grasses, and small patches of sphagnum mosses.

The exposed cut has a vertical face and at the time of observation it was not possible to examine in more detail the stumps that occur at different levels, their relative age, or the periodicity in thin seams of wind-blown silt and volcanic ash which are present noticeably in the earlier stages of peat formation. Capps (5) described a cross section of glacial till overlain by peat with superimposed layers of stumps on the bank of White River below Russell Glacier. From ring counts on a number of stumps it was estimated that the peat material accumulated at a rate of about 1 foot in 200 years and that the ice of Russell Glacier withdrew from that point about 8,000 years ago.

EYAK (NO. 22)

Northeast of the town of Cordova is Eyak Lake, an irregular-shaped body of water in a valley between two ridges of timbered slopes. The lake is fed by Power Creek and Shepherd Glacier and drains through Eyak River to the Pacific Ocean across tidal marshes which border the coast and extend eastward to the Copper River delta. The Copper River railroad follows along the south shore of the lake.

On the west shore, almost within the city limits and opposite Nirvana Recreation Park, is a muskeg which is serving as a burial place, known as the Russian graveyard (fig. 12). The surface is

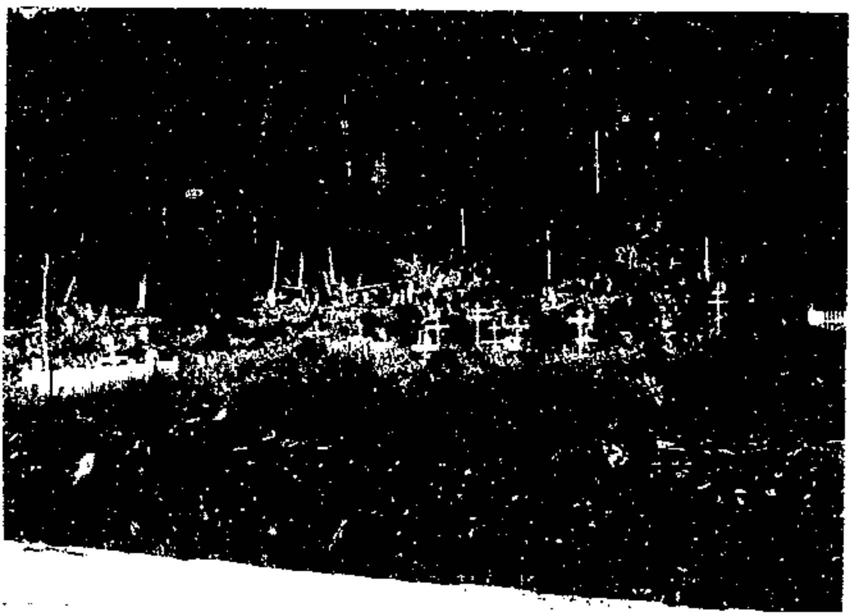

FIGURE 12. Convex-shaped muskeg near Cordova, Alaska, known locally as the Russian graveyard.

definitely convex-shaped, sloping gently from the center towards the periphery. The boundary line is quite irregular and merges gradually into the adjacent woods and a relatively steep slope which ends in forested ridges. On the lake side the muskeg is well drained and the ground cover consists of hummocks of sphagnum mosses which are now dominated by a variety of plants, including sedges and heaths such as *Andromeda*, *Ledum*, *Empetrum nigrum*, *Vaccinium vitis-idaea* var. *minus* and herbs like *Rubus chamaemorus*, *Drosera rotundifolia*, and others. Quite as characteristic are the few scattered spruce and hemlock, dwarfed and rather stunted. Here as elsewhere, the hummocks of sphagnum mosses, rather than sedges, heaths, and conifers, are the most conspicuous plants which could be called typical of raised muskegs.

Profile soundings and measurements, made on cuts exposed along the Government road which follows the west side of the lake, give a record as follows:

0–2½ feet; sphagnum moss peat; spongy, yellowish-brown, strongly acid, shading from hummocks of growing *Sphagnum papillosum*, *S. fuscum*, *S. rubrum* and others, into brown, spongy-fibrous, matted moss peat; the central portion of the layer is much thicker than the sloping margins and characteristic of the greater central growth of mosses under the influence of atmospheric humidity, and the high capacity of mosses to absorb and retain rainfall and prevent its flow outward; wet hollows are revealed by several thin seams of dark-colored, partially decomposed moss peat; some of these extend more or less evenly between former hummocky growths of sphagnum mosses, while others appear to have been small depressions related to shallow pools of water; at the lower level the material is brown and contains woody rootlets.

2½–3 feet; woody peat, consisting of dark reddish-brown woody fragments, bits of twigs and branches, flat-rooted stumps of spruce, fallen timber, cones and leafy litter with crumbly plant remains from grasses and sedges giving evidence of partial decomposition during a dry period.

3–5½ feet; sedge peat; brown, fibrous network of roots and rhizomes from a relatively pure stand of sedges; the material is matted and firm at the lower level, indicative of moist conditions and more recent compaction; the layer conforms in general to the topography of the flat but is rather sharply demarked from light gray volcanic ash, about 1½ to 2 inches in thickness which lies between the sedge peat and the underlying sandy gravel; root channels extend through the volcanic ash to a depth of 5 inches below.

5½–6 feet; dark-brown sandy gravel containing well decomposed organic residue in the upper 4 inches.

Near milepost 4 along the Eyak road, occurs a slope muskeg which ranges from 2½ feet deep at its margins to 5½ feet in the more central portions. It slopes toward the lake and appears to have developed over a glaciated rock outcrop. Brown, felty-fibered sedge peat forms the basal layer. The surface material consists of a relatively thin cover of sphagnum moss peat changing downward to an admixture of sedge peat; below that is a woody layer which lacks well-marked differences such as are characterized by stumps.

Of exceptional interest is the fact that, as a result of road construction, the muskeg demonstrates a breaking and sliding of the surface material at right angles to the general slope. The movement is fairly well illustrated in the accompanying photograph (fig. 13*A*), which shows the unevenness of the surface in consequence of such gliding movement. In northern Canada and Europe this phenomenon happens most frequently in spring when the surface layer is saturated by melting snow and ice and slides over the frozen lower layers (*1*).

It might further be mentioned that several muskegs in the vicinity of Cordova are not of the raised-moor type, although the surface is

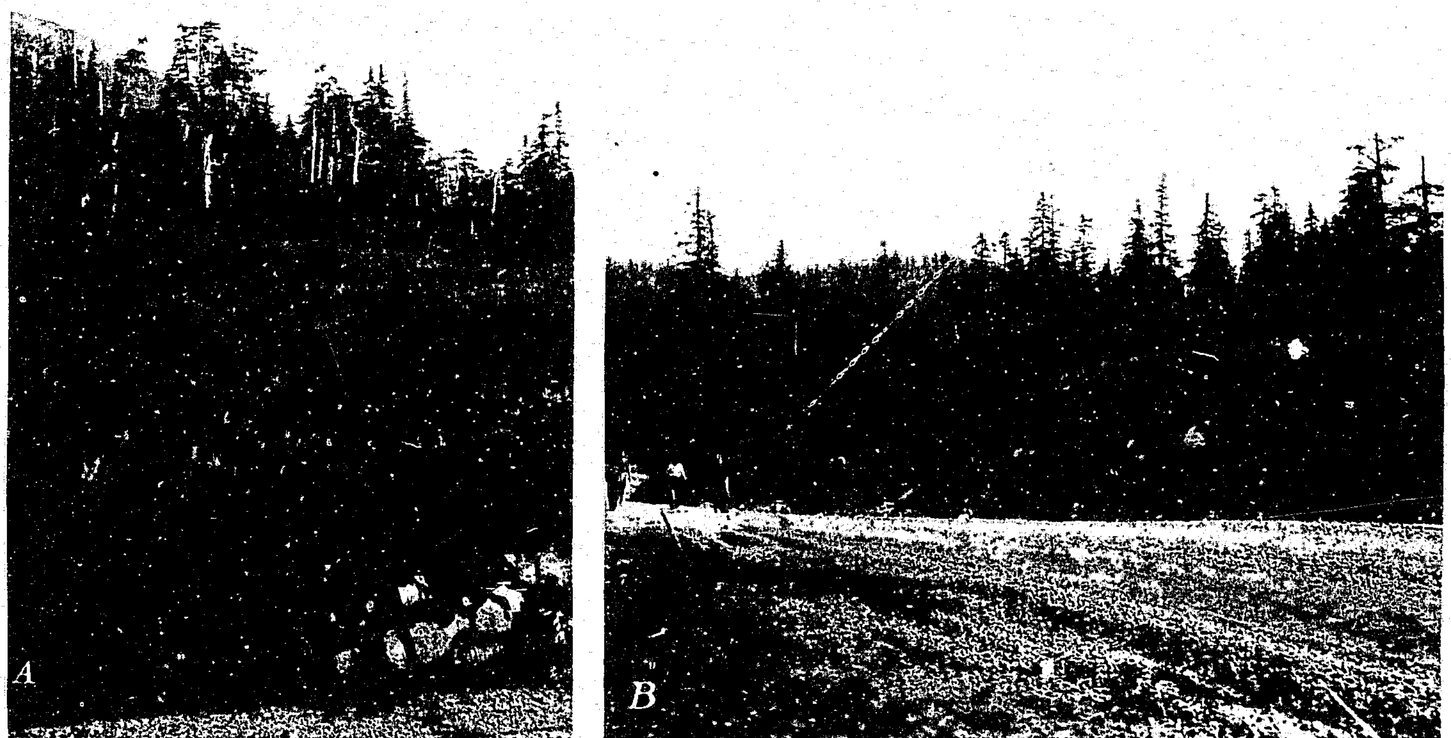

FIGURE 13.—*A*, Muskeg along Eyak Lake Highway near Cordova, Alaska, showing sloping surface and a breaking of the surface in consequence of peat material sliding over frozen layers underneath. *B*, Muskeg with surface sloping from the center toward the periphery. The convexity is not due to the upward growth of sphagnum mosses but to the contour of the underlying mineral material.

characteristically curved. The exposed cross section of the peat area southeast of town near the end of Three-mile road shows a convex surface (fig. 13*B*), which conforms strictly to the topography of the underlying glacial mineral material. The profile indicates that a vegetation of segdes, sphagnum mosses, and low-growing heaths tends to spread uphill. The surface is not level and both the growth of plants and the rate of peat accumulation vary from place to place under the influence of different degrees of moisture content in the respective peat materials.

Muskegs on the Forelands of Prince William Sound

Northwestward of Cordova are a number of low-lying forelands, valleys, and islands regarded by Grant and Higgins (*18*) as parts of a peneplain of an earlier glaciation of the district, but which later was smoothed over by local tongues of glacial ice. In height, the surface of this plain ranges between 20 to 60 feet above the present sea level, rising gradually from the shore to the flanks of the mountains that surround Prince William Sound. The forelands of Bomb Point and Sheep Point and the lowland between Port Gravina and Port Fidalgo belong with this plain as do also parts between Landlocked and Galena bays.

Of particular importance is the evidence reported by Grant and Higgins pointing to relatively recent changes of sea level in certain places of this district. That a recent depression of the shore line has taken place is noticeable on muskegs at Bomb Point, but better illustrated at Fidalgo Bay and Hell's Hole which present more strongly marked evidence of a sinking shore line.

BOMB POINT (NO. 23)

On the southwest end of the peninsula between Orca Bay and Simpson Bay, and especially in the vicinity of Bomb Point, are a number of sloping muskegs locally called tundra. They are generally free of timber except for a scrubby growth of mountain hemlock. The ground cover tends to be uniform in height and consists chiefly of sedges (*Carex* sp., *Rhynchospora* sp.) deergrass, cottongrass, and hummocks of sphagnum mosses with low-growing heaths such as *Andromeda polifolia*, *Ledum groenlandicum*, and several species of *Vaccinium*. Subordinate are deer cabbage (*Nephrophyllidium crista-galli*), patches of club mosses (*Lycopodium* sp.), sundew, cranberry, and others. The water table is near the surface and shallow pools of water are common, giving a reaction between pH 5.0 and 6.0.

Near the head of a lagoon, profile sections were obtained in a muskeg of which the location and general form are shown in fig 14. The average depth of peat is 3 feet and the mineral substratum is a bluish-gray firm silt giving a neutral reaction (pH 7.0). The organic material overlying the silt is brown felty-fibered sedge peat, moderately decomposed and has a reaction of pH 5.5. The peat layer near the surface consists of a thin cover of plant remains derived from sphagnum mosses with an admixture of roots and rhizomes from sedges.

At the western end of the lagoon, soundings taken at several points indicate a depth of 5½ feet of peat. The surface material ranges from yellowish- to reddish-brown and is essentially a varying mixture

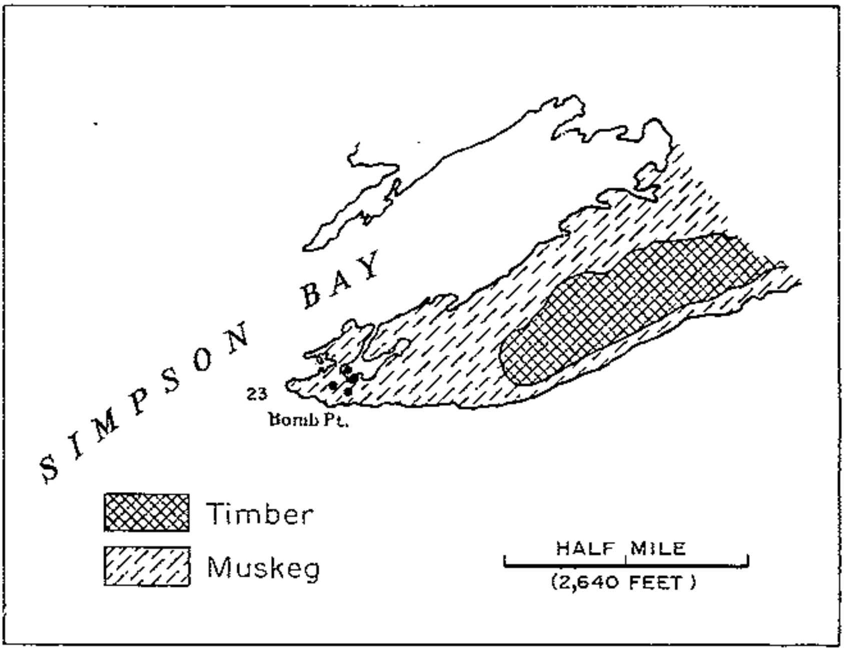

FIGURE 14.—Sketch map showing location of muskeg on north side of Bomb Point, Alaska.

FIGURE 15.—Basal layer of sedge peat sloping into tidal water and exposed by low tide at Bomb Point, indicating a recent sinking of the shore line.

of plant remains from sedges and mosses, similar in composition and character to that described above for the muskeg at the head of the lagoon. Near the 3½-foot level below the surface is a layer of woody peat in which stumps of spruce and hemlock are rooted flat-based; below it occurs reddish-brown, fibrous-matted, and distinctly laminated sedge peat. The mineral substratum, however, is sandy silt and gravel in which occur cobblestones and boulders resembling morainal material; it slopes into tidal water, extends down to low tide, and is being cut into by waves. Rhizomes of *Equisetum* and several sedges as well as seeds of buck bean are present in the surface of the sandy gravel as well as in the layer of sedge peat which contacts it. The lower portion of the wave-cut muskeg with its basal layer of sedge peat and the roots and stumps of conifers, covered at high tide, is shown in figure 15.

SHEEP BAY (NO. 24)

Between Simpson Bay on the east and Port Gravina on the west is Sheep Bay, a northern arm of Orca Bay. Entering it from the west and near the head of Sheep Bay is a small island that viewed from one side appears to be covered with a good growth of sedges, but from another shows hummocks of sphagnum mosses, some of which have a growth of *Empetrum nigrum*, *Rubus chamaemorus*, *Vaccinium vitis-idaea* var. *minus* two species of *Drosera*, and reindeer mosses, while others are disintegrating on the sides, covered with a crust made up of black flakes, revealing on the under surface a layer showing blue-green algae on isolated patches of *Polytrichum* mosses and species of *Cladonia*.

Profile soundings were carried out in several places, both in the center of the peat area and near its margins. All these tests agree in showing a depth of peat ranging between 3 and 4 feet. Sphagnum-moss peat is present in a few inches at the surface; sedge peat, made up of the roots and rhizomes from species of *Carex* and *Scirpus* occurs to within a few inches of the bottom, and a thin layer of woody peat is at the base; it contains no stumps except woody fragments from branches, twigs, and leafy material from deciduous shrubs which give evidence that the muskeg began on a shaly sand and gravel with a type of vegetation dominated by alder, willow, and other shrubs.

GRAVINA POINT (NO. 25)

On the foreland separating Sheep Bay and Port Gravina, muskegs were examined at a place directly north of Gravina Point in a valley whose sloping floor probably belongs to the same lowland as that between Simpson and Sheep bays. Near the head of a small lagoon, on the north side of the foreland (fig. 16), the muskeg is covered with small hummocks of sphagnum mosses. The plants associated with the active growth of the mosses are *Vaccinium vitis-idaea* var. *minus*, *V. oxycoccus*, *Empetrum nigrum*, *Drosera rotundifolia*, *D. linearis*, species of *Pyrola*, *Limnorchis*, *Cladonia*, and others. Spruce and hemlock are much dwarfed and widely scattered, while heaths such as *Kalmia*, *Ledum*, and *Andromeda* occur in patches with taller shrubs of *Menziesia*, *Myrica*, and *Salix*. Seedling trees are not frequent in this community, and herbaceous plants such as *Rubus chamaemorus*, *Pinguicula villosa*, *Cornus canadensis*, *Viola palustris*, and species of

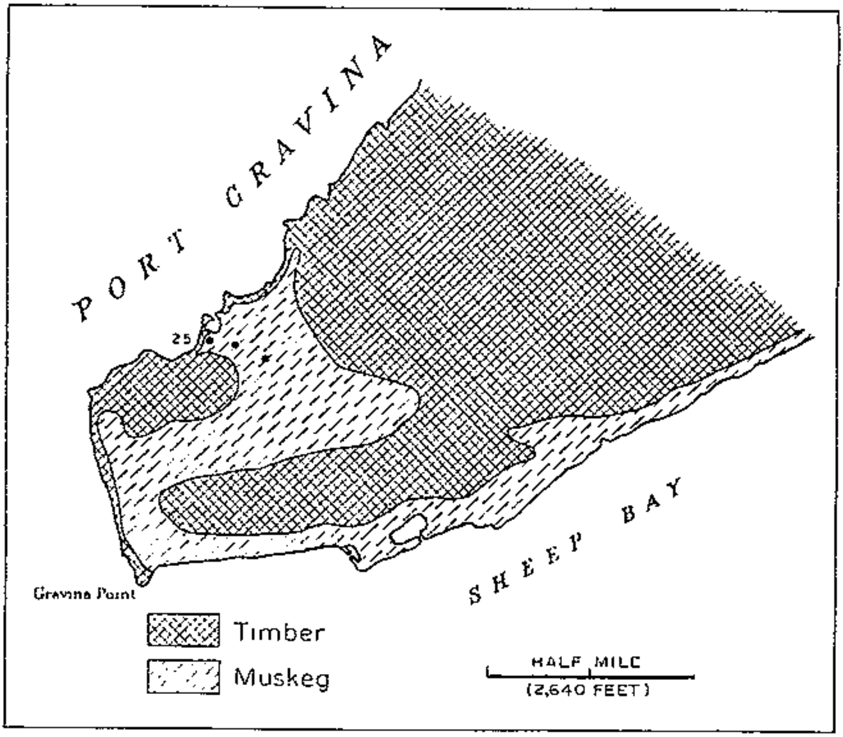

FIGURE 16.—Sketch map showing location of muskeg on lagoon north of Gravina Point, Alaska.

FIGURE 17.—Small pools of stagnant water on slope muskeg near Gravina Point Alaska.

Limnorchis, *Veratrum*, *Unifolium*, and others are represented only by occasional plants. The salient feature consists in the distribution of the dominants of the ground cover. On the higher slope of the muskeg the vegetation includes more sedges and cottongrass (species of *Carex*, *Scirpus*, and *Eriophorum*) but the surface is intersected by a network of small, shallow pools tending to be circular in form (fig. 17). The aquatic vegetation consists mainly of isolated patches of *Menyanthes trifoliata*, *Myriophyllum* sp., *Potamogeton* sp., and various forms of algae, including *Nostoc* and soft nodules of blue-green algae forming a granular gelatinous mass.

Profile soundings, made in various places, passed through a thin upper cover of yellowish-brown mixture of moss and sedge peat; below it is a layer of reddish-brown felty-fibered sedge peat ranging in thickness from 1½ to 3 feet which merges with the underlying sandy gravel.

Along the shore line the muskeg is bordered by outcrops of rock and a belt of fairly tall timber, mainly spruce and hemlock. Much of it has a luxuriant undergrowth of devilsclub, salmonberry (*Rubus spectabilis*), *Menziesia ferruginea*, several ferns, and a ground cover in which *Hypnaceae* predominate. A number of trees have been killed by high tides, which may possibly be due to a depression of the lowland already described.

HELL'S HOLE (NO. 26)

One of the most characteristic forelands with evidence pointing to a recent sinking of the shore line is the point of land which separates Port Gravina from Port Fidalgo (fig. 18).

On the south side of the land and northeast of Red Head near the north side of Port Gravina is a small bay known as Hell's Hole. Shallow water and a quantity of sand and gravel overlying 2 feet of firm matted sedge peat have greatly increased the beach area. New bars have been built up nearly half a mile seaward from the beach, while back of the strand, in the quiet and more sheltered places, small dunes are frequent with a plant cover distinct from that of the adjacent muskegs. The colonizers and stabilizers of the sand are *Lathyrus maritimus* and *Mertensia maritima* along the front of the dunes, creeping in among the culms of *Ammophila arenaria* and *Elymus mollis*. Driftwood and loose unanchored sand are confined to the beach alone while blowouts are rare.

Back of the dunes are trailing herbaceous vines, a lupine, *Potentilla fruticosa*, *Spirea* sp., *Calamagrostis scabra* and others, giving way inland to a thin fringe of timber which borders the extensive and poorly drained muskeg.

In composition the surface vegetation of the sloping muskeg resembles those along Port Gravina. Cushions and hummocks of sphagnum mosses are of relatively subordinate importance in comparison with the part played by *Scirpus* sp. and sedges. Spruce trees are dwarfed and widely scattered, and mountain hemlock takes on a fan-shaped form. Heaths constitute the more vigorous plant growth. *Myrica gale* and both high-bush and low-bush species of *Vaccinium* are common, and there is considerable variation in the composition and size of isolated clumps of shrubs; but they do not seem to be dominant or abundant enough to justify a description of the muskeg as a heath-covered lowland or tundra. The surface is dotted with shallow pools of water, characterizing the high water-holding capacity of the peat material. There are hollows exposing the underlying morainal sand and gravel, but they are doubtless a reaction to snow and ice which fill the depressions during the winter and presumably retard the growth of plants for a considerable period during the summer season. Moreover, summer thawing and drainage goes much deeper in the bare spots than in the plant-covered portions of the muskeg.

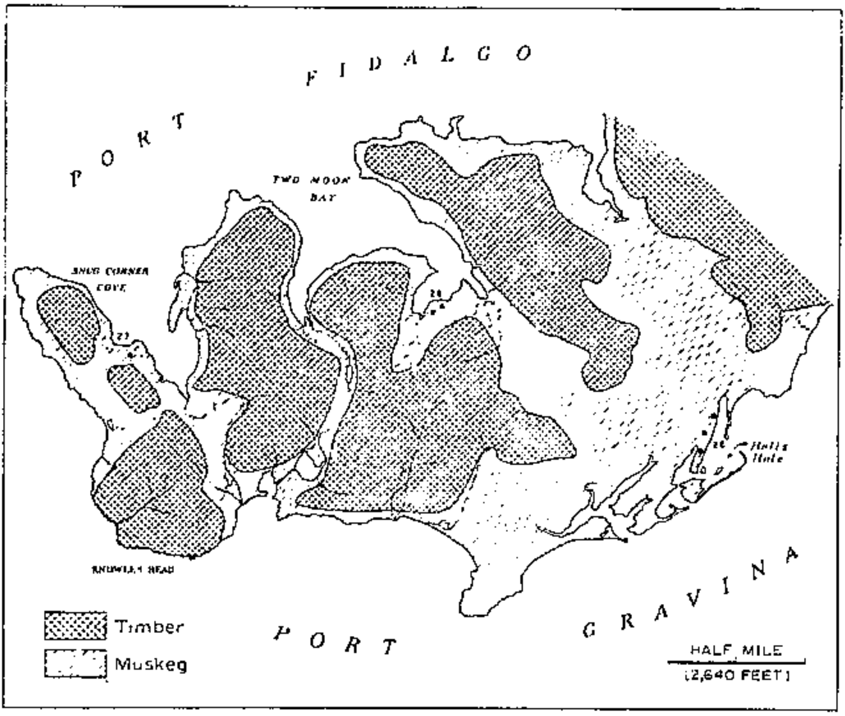

FIGURE 18.—Sketch map of foreland between Port Gravina and Fidalgo Bay showing location of Hell's Hole, Snug Corner Cove, and Two Moon Bay muskegs.

Profile soundings indicate depths of sedge peat ranging between 3½ and 5 feet. Cross-sections cut at low tide along the banks of a small unnamed stream which enters the muskeg from wooded slopes, reveal nearly 6 feet of sedge peat. Differentiated on the basis of the more prominent features the cross-sections show:

0–5½ feet; upper few inches composed of a mixture of sphagnum moss and sedge peat grading into brown fibrous, matted sedge peat, fairly uniform in texture and composition toward the 4-foot level; between 4 and 4½ feet below surface the material is stringy-fibered, rather coarse, permeable, and contains many rhizomes from *Scirpus* sp.; near the bottom, the sedge peat has a larger content of black-colored rhizomes from *Equisetum* sp. and many flat rhizomes as well as seeds from *Menyanthes trifoliata;* root channels extend into the underlying morainal material which is nearly 1½ feet below tidewater.

5½–6 feet; grayish-brown silt over light-gray sand and coarse gravel.

On the bay side, the lower portion of the layer of sedge peat is over 2 feet below sea level; it extends out over a distance of 70 feet from the shore, indicating a sinking of the land at least several feet below the present ocean level. The general features of the shore are illustrated in figure 19.

SNUG CORNER COVE (NO. 27)

This cove is a small projection from Port Fidalgo back of Knowles Head on the northwestern edge of the foreland (fig. 18). The topography of the adjacent lowland is more rugged than that typical of other sections on the coast. In some places it is narrow with steep slopes and in others it widens with benchlike formations sloping gently from the shore line to varying elevations above sea level.

The muskegs situated on the west shore of the cove are similar in surface vegetation to the slope muskegs previously described, but the profile soundings show that the depth of peat is rarely over 4 feet in thickness. The organic material varies somewhat in physical characteristics and composition. In general it consists of felty-fibered sedge peat, chocolate-brown, pH 5.0 in reaction, more or less waterlogged, and laminated between 2 and 3½ foot levels, yellowish-brown and firm near the 4-foot level and somewhat woody. An admixture of sphagnum moss peat occurs at the surface in the upper 2 or 3 inches, but in many places moss peat is entirely lacking.

The mineral substratum is a bluish green sand and gravel and contains iron-stained root channels.

An interesting feature is old trails leading to the beach and worn deep into the sedge peat. They are the result of wildlife traveling over the matted heath vegetation. In some places the trails appear to become gullies and may lead to conditions described for stream banks in the muskeg at Hell's Hole.

TWO MOON BAY (NO. 28)

This bay is an eastward projection of Port Fidalgo, lying between Snug Corner Cove and Irish Cove. The bounding lowland is rather steep and rugged but much of the enclosed area is of low relief and includes a number of muskegs. The deposit of peat examined is on the east side of the bay (fig. 18). It is a sloping expanse, beginning at the bay and extending ridgelike to the timber at the upper end of the slope. Some parts of it along the shore have been cut by wave erosion, exposing 4 feet of brown fibrous and more or less laminated sedge peat. The material rests on sand and gravel as well as on bedrock along the shore.

The muskeg has the aspect of a sedge marsh from the number of sedges and cottongrass that grow upon it, but in the ground cover are sphagnum mosses and a large variety of herbaceous plants. Characteristic among these are *Coptis trifolia*, *Cornus canadensis*, *Pinguicula villosa*, *Caltha biflora*, *Rubus chamaemorus*, *Sanguisorba microphylla*, species of *Trientalis*, *Limnorchis*, *Viola*, *Unifolium* and others. They are never predominant in any place and form a rather small percent of the plant cover when compared with the distribution of local patches composed of such heaths as *Empetrum*, *Vaccinium*, *Andromeda*, *Kalmia*, *Ledum*, and the bayberry (*Myrica gale*).

FIGURE 19. A part of the sinking shore line of Hell's Hole Bay. The rubble in the foreground is underlain by sedge peat, giving certain evidence of relatively recent changes in sea level.

Landward where the slope becomes steeper, the sedges and heaths are invaded by spruce and mountain hemlock. The peat material is brown fibrous sedge peat and ranges in depth from 1 to 2 feet, depending on the angle of slope. Some of the higher islandlike rock outcrops are timbered and have a luxuriant undergrowth of ferns, devilsclub, alder, berry-bearing shrubs and mountain-ash, in marked contrast to the sparser vegetation on the general surface of the muskeg. The soil consists of a large amount of decaying leafy and woody material, is thickly interwoven with woody roots, and is generally covered with Hypnum mosses, characteristics of forests. Where wildlife has worn deep trails into the matted peat, the vegetation on both sides of the trails leading to the shore are sphagnum mosses and *Empetrum nigrum*; they tend to be replaced by sedges and heath shrubs in drier conditions.

FIDALGO BAY (NO. 20)

At the extreme head of Port Fidalgo are fairly flat but sloping lowlands of silt and sandy gravel which in places along the shore cover an underlying layer of fibrous sedge peat. On the southeast side of the bay, the evidence of recent changes of sea level is particularly well marked.

At a locality, shown on the sketch-map (fig. 18), the lower peat layer of the muskeg extends at least 2 feet or probably more, below tide, and the shallow water near the shore is possible due to this subsidence. There are a number of stumps, exposed by the tidal wash, which rest on sedge peat, and correspond with similar stumps at the same level in the interior landward side of the muskeg.

Much of the muskeg bears a surface vegetation which is like that of the muskegs previously described. All the soundings agree in showing that the depths of peat on the upper slopes range from 2 to 4 feet. Most of the material consists of reddish-brown fibrous sedge peat which at the surface contains small amounts of sphagnum moss but at the lower level consists of sedge peat with a grayish tint; the material is moderately decomposed, and grades into sandy gravel. Thicknesses of peat increase toward the lower slopes, but profile sections in which the basal layer of sedge peat is below sea level do not exceed 8 feet in depth.

Where the muskeg is more poorly drained, specialized habitats like shallow pools of water are quite numerous at all elevations. Near the shore line, however, where there is more movement of ground water, sphagnum mosses and sedges do not occur. Tall-growing spruce and hemlock have established themselves, forming a thin fringe of timber. There is, furthermore, a corresponding alteration of the sedge peat in which the roots of trees are growing. Typical cross sections of the muskeg exposed by the tides and observed in vertical cuts as well as large blocks of peat which fall outward along the shore, reveal the following changes in profile features:

0–10 inches: woody sedge peat; dark-brown, crumbly, partially decomposed; contains small amounts of leafy litter and woody fragments at the surface and beneath it a dense network of fine roots of the growing herbaceous plants; woody roots of trees and shrubs are penetrating to a lower level.

10–65 inches: sedge peat; the upper portion consists of dark-brown, partly fibrous and brittle peat and is occupied by woody roots from trees and shrubs some of which are flat-based, while others extend downward through a reddish brown matted sedge peat to the second foot level; between the third and fifth level the sedge peat is brown, firmly matted, layered, and compacted. Tidewater is 5½ feet below the surface.

65–73 inches: woody peat; dark-brown, granular, and fine-grained organic residue, woody, containing stumps of spruce which correspond with those along the shore and exposed by tidal waves.

73–90 inches: sedge peat; brown fibrous sedge peat, matted, very firm, partly decomposed, with a strong odor of hydrogen sulfide; former root-channels extend into the underlying mineral material.

90–98 inches: bluish-green silty sand and gravel.

The evidence, it will be seen, includes both an old beach line which at one time was 2 to 4 feet or more above the present high tide, and a forest stage in the development of the muskeg which can be correlated with a former drier and warmer period. The developmental changes indicated by the entire profile section of the muskeg correspond, in a general way at least, to those that affected the muskegs in southeastern Alaska.

Muskegs of the Kenai District

The western portion of Southcentral Alaska includes Kenai Peninsula, bounded by Prince William Sound on the east, the Pacific Ocean and its warm Japan Current on the south, and Cook Inlet on the west. Except for a strip across the western side, the peninsula lies entirely within the Chugach National Forest. Seward is the principal town. It is the ocean terminal of the Alaska Railroad and is served by regular mail and passenger boats from Seattle, Wash.

The surface of the peninsula presents two widely differing physiographic features. The eastern part is characterized by high rugged snow-covered mountains, 5,000 to 7,000 feet in elevation, and valleys deeply cut by the former action of ice. The western part consists of a broad sloping lowland into which flow the larger streams that have their source in the large glaciers in the Kenai Mountains.

Kenai Peninsula is quite heavily timbered in most of its valleys up to elevations of 1,200 feet above sea level. Spruce is the more abundant timber but hemlock is found in some localities and also birch, alder, and willow. The investigation of muskegs was carried on only in the eastern portion of the peninsula, but in any comprehensive study of peat resources, those of the western portion would be worthy of consideration. The soils and agriculture of the peninsula, including muskegs and their distribution, have been reported by Bennett (*2*) in a reconnaissance survey made in 1916.

MOOSE LICK (NO. 30)

North of Kenai Lake a Government road extends from the Alaska Railway over Moose Pass and the valleys of Quartz, Canyon, and Sixmile creeks to Hope on Turnagain Arm. The creeks meander through comparatively flat glaciated valleys, in which are located a number of muskegs at elevations over 800 feet above sea level. In many places high benches slope toward the valleys in more or less sharply defined terraces. They consist generally of washed gravel, sand, and bluish-gray clay, derived in large part from the rocks of the neighboring mountains. Moffit (*27*) reports that the sands in the bench deposits are not firmly packed; they carry a large amount of ground water which may come from a source outside the glacial material. Sufficiently detailed studies have not been made, however, to determine the character of the ground water or the nature of the various muskegs and the feasibility of their commercial development.

Evidence that some of the muskegs in the mountainous district are of the raised type and present a contrast to those developing on the coastal lowlands farther south, is seen in the Moose Lick muskeg reached at mile 42.5 by way of the Cooper Landing Government road. The general view given in figure 20 shows the condition at this point. The difference is largely in the reduction of sedges and in a corresponding increase in hummocks of sphagnum mosses, but other features are in relation to successional stages. The center of the muskeg, corresponding with a higher water level and a moderately convex surface, is occupied by an association complex in which sphagnum mosses (*Sphagnum cuspidatum*, *S. medium*, *S. warnstorfii* and others) predominate over cottongrass (*Eriophorum sp.*, *Rhynchospora sp.*) and herbaceous plants; surrounding the mossy carpet are local patches of woody shrubs, among them *Ledum palustre*, *Andromeda polifolia*, bayberry (*Myrica gale*) and dwarf birch (*Betula glandulosa*) in a ground cover of *Empetrum nigrum*, *Vaccinium vitis-idaea*, *var. minus*, lichens and others. Nearer the peripheral margin of the muskeg, the plant communities are mixed and diversified by a scattered growth of dwarfed spindle-shaped spruces (*Picea glauca*, *P. mariana*); they may be regarded as transitional changes, due to a lower-ground water level and less acid conditions near the sand and gravel bluffs of the valley.

A point of special interest in this connection, however, is that portion of the road bank through which water, mildly alkaline in reaction (pH 7.5–8.0), is seeping into the muskeg. By contrast the ground water in the moss peat which fringes the tract is very strongly acid (pH 4.5), and there is as yet no sharply marked difference in the surface vegetation. From observations of wildlife trails, however, it appears that moose in rather large numbers frequent this small area (fig. 20, *B*). In addition to moose, other forms of animal life are found to range over the muskeg, probably on account of the saline character of the seepage water and the requirement of nutritious mineral salts.

Profile soundings and pits dug at various places show only minor differences in depth and structural relations. The following represents practically an average of vertical cross sections:

0–4½ feet; sphagnum moss peat; the uppermost foot consists of reddish brown spongy-fibrous, well-preserved moss peat in which are thin roots of the growing plant cover; between the second and the third foot level the moss peat is very firm and contains at the lower level leafy fragments from birch and heaths, needles, woody material, and roots from spruce; at intervals are thin seams of dark-brown, partly decomposed moss peat which represent small and local wet depressions; near the fourth foot level the moss peat is very firm; it contains volcanic ash of fine-grained, almost glassy texture, and matted roots from cottongrass and sedges.

4½–6 feet; sedge peat; reddish-brown fibrous sedge peat with an admixture of material from sphagnum mosses; the lower part of the layer contains dark-brown well-decomposed woody material and fragments from shrubs.

6–6½ feet; very firm gray silt over sandy gravel.

The number of soundings made is not large, but it is believed that the quality of the moss peat is representative of the peat area and that the upper layer has commercial value.

MOOSE PASS (NO. 31)

On both sides of the Seward Hope highway, between miles 51 and 52, the road crosses muskegs on flats near the summit, which are dominated by sedges but show various phases of succession. In general, they are treeless marshes that are passing through developmental stages, with sphagnum mosses storing water, and with spruce and heaths where the change in conditions is accompanied by lowered water levels. In places where the accumulation of plant remains continues upward and the roots of growing sedges are removed more and more from ground water containing mineral salts, the marsh vegetation furnishes the conditions for the establishments of sphagnum mosses which depend for their growth upon atmospheric water. However, ground-water conditions are unfavorable for the mosses and in marginal places decomposition of peat material exceeds accumulation of new plant remains. Various heaths and conifers are colonizing these sections increasingly. That this has taken place also in former times and on a much larger scale, has been shown by means of profile sections recorded elsewhere in this report.

In the Moose Pass muskeg the present changes in vegetation are not retrogressive, but are a transitional zonation, corresponding with differences in the water table. Soundings in the portions of the muskeg supporting dwarfed spruce and birch show a thin surface layer of dark-brown sedge peat, largely decomposed, containing dry leafy litter and woody material; the water level is below the surface. Farther in, where hummocks of sphagnum mosses with associates such as sundew, gold thread, and others are frequent, the surface material is saturated with water and consists of fibrous sedge peat and plant remains from mosses and herbaceous vegetation.

Profile sections on the areas dominated by sedges are generally with water at or near the surface. The following represents structural features which are common to the transitions just described:

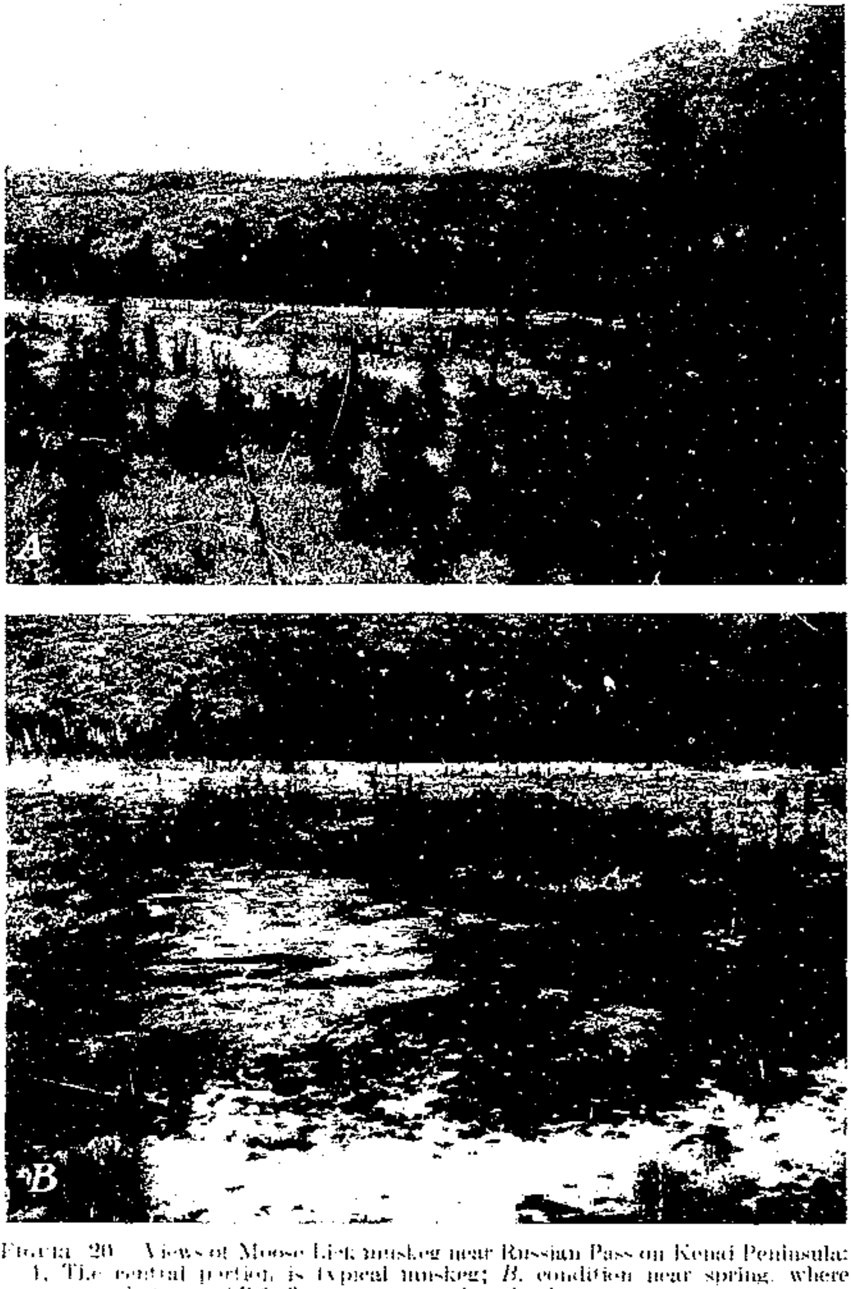

FIGURE 20.—Views of Moose Lick muskeg near Russian Pass on Kenai Peninsula: *A*, The central portion, is typical muskeg; *B*, condition near spring, where moose and other wildlife find necessary mineral salts.

0–6 feet; sedge peat; reddish-brown, felty fibrous material consisting mainly of a matted network of fine roots, basal sheaths and flattened rootstocks from various sedges and grasslike plants; air-dried material is brittle; at lower levels the layer contains colloidal constituents, wind-blown leafy fragments, and small woody roots and twigs; near the bottom the peat material is sandy.
6–6½ feet; gray sand, very firm, on slaty gravel.

The vegetation, history, and botanical composition of the muskeg indicate its origin and stratigraphic structure as well as its present transitional aspects.

SUMMIT LAKE (NO. 32)

In the high valley near Summit Lake (elevation 1,310 feet) and at mile 41.5 and 48.5 on the Seward-Hope highway, muskegs occur which form a border along open water or occupy flats. On the whole, the surface vegetation has the aspect of the preceding muskegs described above. Associations of sphagnum mosses, heaths, and conifers are in a state of transition. The existing climate tends to make their own continued existence difficult, furnishing conditions for the natural succession of conifers.

Profile sections afford a measure of the relative duration of each group of peat-forming vegetation and they confirm the conclusion, reached in this way, that sphagnum mosses have appeared only recently, and that woody shrubs and conifers tend to replace the species which colonize marshes with higher water levels. Vertical cross sections of these muskegs are generally as follows:

0–5½ feet; thin cover of sphagnum moss peat, carrying woody material in places where spindle-shaped spruce and low heaths are dense; below this the sedge peat is reddish brown in color and comprises occasional bands of yellowish brown fibrous matted material, interbedded with finer organic sediments; near the base of the layer, the sedge peat is gray-brown and fibrous but includes fine organic residues and gray sand.
5½–6 feet; bluish-tinted gray sand resting on coarse gravel.

Muskegs of the Anchorage District

The chief geographic features of this district are the mountains which form a spur of the snow-covered Chugach Range, and the valley floors that blend with terraces and flats and are composed of sand and gravel supplied by former valley glaciers. These deposits were laid down by the action of ice and reworked by water and are thick enough in places to conceal the bedrock. All of the glacial streams, particularly the Matanuska, Eagle, and Knik rivers, are carrying and depositing silt, sand, and gravel, dissecting and eroding the gravel benches around Anchorage, with the aid of tides which are slowly undercutting the bluffs facing Knik Arm and Cook Inlet and exposing peat deposits.

The district, lying as it does back from the ocean, has a climate more like that of the interior of Alaska. Precipitation is light, especially during the rather mild summer season when only a few inches of rainfall may occur. The winters are severe but the snowfall is said to be moderate, usually up to a total of 3 or 4 feet of snow accumulating annually.

The surface of the terraces and flats is generally well forested with the exception of the lakes and muskegs, and the belt of sand dunes along river bends. Dust storms are frequent in the valleys, caused by the strong down-valley movements of the cool air overlying the glaciers, displacing the hot air in the lower valleys, picking up silt and sand from the river flood plain, and piling up sand in dunes and wind-blown silt over the valleys.

Bennett and Rice (*2, 3*) mapped the soils of a portion of this district during reconnaissance field work in 1914 and 1916, using topographic maps prepared in connection with the geological survey of this region.

More recently (1938), the Alaska Planning Council has sponsored a soil conservation survey and economic study of the Matanuska Valley in cooperation with W. A. Rockie of the Soil Conservation Service. The Alaska Railroad crosses this area and much of it is now accessible by a network of highways. A branch of the railroad runs from Anchorage along the Matanuska River to Chikaloon.

SPENARD (NO. 33)

About 5 miles southwest of Anchorage, at the end of the Spenard Road, are muskegs with several unnamed small lakes. Field observations show that in an otherwise flat surface lying within the 100-foot contour line, depressions of varying size were occupied by a shallow lake. Peat began to accumulate as a marginal deposit, continued over low ridges that crossed the lowland in several places, and subsequently filled the depression, with the exception of the still remaining ponds as the last remnant of the former larger lake. This view was confirmed when soundings were undertaken and test pits were examined along the line of a proposed channel connecting Lake Spenard with Lake Hood.

The muskeg has a concave form and is bounded by rising ground fringed with a border of scrubby black spruce and an associated undergrowth of birch, alder, and shrubby heaths. The organic material on the surface consists of a dry litter of needles from conifers and leaves from heaths with fungal hyphae, representing a poorly decomposed, acid raw "mull." Below it, the plant remains form a mixture of partly decomposed fibrous sedge peat with sphagnum mosses, woody roots and varying amounts of coarse rootshoots from shrubs. All the soundings, including those made in a muskeg on the east side of Lake Spenard, agree in showing that between the first and fifth foot level the material is chiefly reddish-brown fibrous sedge peat with a thin seam of volcanic ash approximately 4 feet below the surface. Between the 5- and 8-foot level, the material is composed of yellow-brown Hypnum peat characterized by species that form floating mats in open water. The underlying mineral material is coarse sand, greenish gray in color.

In passing from the timbered phase of the muskeg, along the relatively drier margin with a water table fluctuating between 10 and 14 inches, to the wetter conditions around the ponds, the conifers diminish in size and are scattered in an undergrowth of dwarf birch (*Betula glandulosa*), bayberry (*Myrica gale*), shrubby cinquefoil (*Potentilla fruticosa*) and a ground cover consisting of *Scirpus caespitosus*, several sedges not readily distinguishable from cottongrass, and a variety of sphagnum mosses. Hummocks of mosses increase in height around tree trunks and in the intervening spaces between the taller heaths such as *Kalmia*, *Ledum* and *Andromeda*. Typical plants indicating association with sphagnum moss cushions are *Rubus chamaemorus*, *Drosera rotundifolia*, *Empetrum nigrum*, small-leafed cranberry, and others.

The complex of plant communities situated in the central portion of the muskeg is characterized by species of sphagnum mosses which dominate wet hollows (*Sphagnum cuspidatum, S. cymbifolium*) and the more active hummock builders (*S. medium, S. papillosum, S. fuscum* and others), which cover the mounds. Some of the larger hummocks are capped with cranberry, sundew, clubmoss, small seedlings of spruce, and a few low-growing heaths.

Around the open water are quaking mats composed of sphagnum mosses, some of which are emerald green in color, interwoven with the slender stolons, rhizomes and rootlets of a number of sedges and cottongrass. In the open water occur communities among which are species such as *Menyanthes trifoliata*, yellow waterlily (*Nymphaea* sp.), and submerged forms of *Ceratophyllum*, *Potamogeton*, and a few others.

Profile soundings near the margin of the open water gave the following record:

0–8 inches; sphagnum moss peat, yellow brown in color, spongy fibrous, embedded in a network of rhizomes and roots of growing sedges.

8–60 inches; sedge peat, brown coarse-fibered, loosely matted and waterlogged; the material is reddish-brown at the lower level and contains a thin seam of volcanic ash between 3 and 4 feet below the surface.

60–130 inches; hypnum peat, yellowish brown in color, relatively well preserved, finely fibered near the bottom; contains rhizomes and seeds of *Menyanthes* sp., and plant remains from herbaceous aquatic vegetation.

130–140 inches; sedimentary peat, fine-grained, more or less colloidal in structure and light brown in color; the transition to underlying mineral material is not well marked.

140+ inches; firm gray sand over coarse sand.

It is thus evident that the vertical sequence of peat layers is a means of establishing also the ecological succession of plant associations and the changes in environmental factors, and of indicating, moreover, the extent to which the horizontal transitions of today have undergone changes in botanical composition. Sphagnum mosses are, doubtless, a dominant of recent times and soon to be replaced by vegetation indicating drier conditions.

MERRILL FIELD (NO. 34)

Southeast of Anchorage, about 1½ miles, is the airport Merrill Field from which a road passes to the lower valley floor. The lowland has interrupted strips of muskeg in some places, and fairly large muskegs in others. They usually have a stand of spindle-shaped black spruce, ranging in height from less than 5 feet in wet spots to about 12 feet in drier sections. This is particularly noticeable near the marginal bluffs. Within the muskeg the vegetation tends to be more uniform and the dominant species among the shrubs are dwarf birch, cinquefoil, bayberry, two species of *Ledum*, and a low willow. The salient feature of the ground cover consists of cushions of sphagnum mosses on which are to be found a variety of plants. In the order of abundance, they are: *Vaccinium vitis-idaea*, var. *minus*, *Cladonia rangiferina*, *Rubus chamaemorus*, patches of *Polytrichum* and *Eriophorum* sp. with *Scirpus caespitosus*. The depressions between the mounds support several sedges, *Equisetum* sp. and isolated bushes of dwarf blueberry (*Vaccinium caespitosum*, *V. uliginosum*). Much of the vegetation is water-logged in the central portion of the muskeg except for small islands and ridges whose surface is higher and generally represents a timbered phase.

Profile soundings were taken in several places over this area. In the marginal portions, averaging 30 inches in depth, the upper 5 inches consist of reddish-brown sphagnum moss peat which is sharply demarked from a lower layer of dark-brown woody material in an advanced degree of decomposition; below the 17-inch level the material consists of brown, coarsely fibered sedge peat shading into grayish-brown silt which contains organic residue and root channels of sedges; the underlying mineral material consists of firm sandy gravel.

Centrally located profile soundings gave an average of 6 feet of peat on sandy gravel. Intermediate test pits, excavated by members of the C. C. C. organization, reveal a thickness of peat averaging 5 feet. The general features of profile sections are as follows:

0–8 inches; brown sphagnum moss peat which contains many rootlets, rhizomes of sedges and woody roots of shrubs; below it is a thin layer of ash, brick-red in color, probably iron-stained, which rests on woody material.

8–25 inches; brown moderately well-decomposed woody fragments, varying in size, derived chiefly from a stand of spruce timber; it contains an admixture of sedge peat at the lower level.

25–54 inches; grayish-brown somewhat silty sedge peat, matted-fibrous; toward the base of the layer, the material is laminated and made up, in part, of Hypnum mosses, contains rhizomes and seeds of *Menyanthes trifoliata* and fine-grained organic matter derived from aquatic vegetation.

54–61 inches; transition to sandy gravel.

While the two muskegs in the vicinity of Anchorage have been selected for description of flat types, it may be of interest to indicate briefly the main features of a raised type of muskeg near Palmer in the contiguous Matanuska Valley. The modifying influence of the warm coastal waters and the protecting mountain range give the valley a climate which lacks the extremes of temperature that characterize the great interior valleys of the Yukon and its tributaries.

PALMER (NO. 35)

The muskeg examined near Palmer lies three-fourths of a mile south of town in section 4 of T. 17 N., R. 2 E. It is a small area enclosed on three sides by a fairly tall and dense stand of timber, chiefly spruce. The surface is characteristically convex, sloping from the center towards the periphery where it merges with the trees of the forest. The marginal slope is occupied by a dominant growth of heath shrubs such as *Ledum*, *Andromeda*, *Kalmia*, and *Vaccinium*, and occasionally colonized by seedlings of black spruce and birch. Along the margins there is no trace of seepage or a type of marginal ditch (lagg) which is known to be a feature of some European raised moors. The surface vegetation growing in the center of the muskeg contains most of the species reported for the raised type of muskegs farther south. There are spongy hummocks formed by the active growth of *Sphagnum fuscum*, *S. medium*, *S. acutifolium* and others, and wet depressions in which *S. squarrosum* and *S. cuspidatum* are dominant. Most of the drier hummocks are clad by *Empetrum nigrum* and *Vaccinium vitis-idaea* var. *minus*. Subordinate species are dwarf cranberry, sundew, *Rubus chamaemorus*, and isolated patches of deergrass, cottongrass, and a few lichens of the reindeer moss type (*Cladonia* sp.) Brownish-colored patches on the mounds are generally invading *Polytrichum* *commune* which, however, do not represent a feature of retrogression or desiccation.

Changes which result from a denser colonization of heaths have not been observed. Very little zonation of vegetation is to be seen except as the outer margin of the muskeg is approached, in which transitions occur and the mounds of sphagnum mosses are relatively drier and *Vaccinium vitis-idaea* var. *minus* becomes more abundant.

Profile soundings were made at several points; together with an excavation, they give the following features of interest in this muskeg:

0–25 inches; moss peat, light yellowish brown in color, relatively well preserved and spongy-fibrous; no appreciable differentiation is visible between the material of which the hummocks are composed and the moss peat into which it shades to a depth or 20 inches; the upper 14 inches contain roots, stolons, and rhizomes of the growing vegetation and an occasional stump of spruce; the moss peat below that level is frozen; it contains a thin seam of gray fine volcanic ash, approximately two inches in thickness on which the flat-rooted stumps of spruce appear to have become established; below the frost line the moss peat is darker in color, compact, and contains solid ice; it is interrupted by another thin seam of volcanic ash near the 27-inch level, and covers an underlying layer of frozen woody peat.

27–31 inches; woody peat, dark brown in color; consists mainly of accumulated material from spruce and birch, woody shrubs, needles, and leafy fragments.

31 inches; transition from gray silty organic residue to gray firm silt, permanently frozen.

From the facts stated above it appears that throughout the profile section traces of wind-blown silt and sand seem to be of small importance. If the thickness of 14 inches of moss peat between the present surface of the muskeg and the layer of stumps near the frost line represents the accumulation during the lifetime of the buried stumps, it should be possible to determine the rate of peat accumulation by ascertaining the age of the stumps and recording any variations in tree-ring thicknesses.

Of much significance is the fact that the line of permanent ground frost has been rising with the constant thickening of the moss peat and its insulating effect (*30*). It might be assumed, therefore, that climatic changes within the valley are favorable for a rising level of frozen peat, cutting off the supply of water and nutrients from the lowest roots of the growing vegetation. This is not consistent, however, with the evidence supplied by cultivated fields, cleared out of the virgin forest which soon lose all trace of frost-bound soils, and by the muskegs themselves in which forests are now advancing into the treeless portions that are covered with sphagnum mosses and tussocky sedges.[4]

WASILLA (NO. 36)

Between Palmer, the Matanuska Agricultural Experiment Station, and Willow Creek lies a succession of muskegs bordering small lakes or occupying sharply-defined basin-like depressions. A few of the

[4] In Cook Inlet near Point Woronzof southwest of Anchorage, an excellent exposure of a muskeg along a newly cut bluff reveals that its history has been of much the same character. The cut bank has very steep slopes, and as erosion takes place by the tides, large blocks of the overhanging face fall outward and down to tide level. At the base of the bluff is bluish sticky clay with an even surface. Above the clay and extending nearly to the top of the bluff are layers of coarse gravel and greenish-gray sand with slightly uneven, rolling surface. Over the surface of the bench deposit is a thin layer of volcanic ash on which a forest of spruce, birch, and associated undergrowth developed and accumulated several inches of woody peat. The forest was replaced by a vigorous growth of sphagnum mosses and tussocky sedges that accumulated over 10 inches of peat. A second layer of volcanic ash, nearly 6 inches thick, interrupted the growth, but sphagnum mosses and sedges again colonized the area: they continued, intermittedly, accumulating 18 inches of peat composed for the most part of a mixture of moss and sedge peat. The quantity of volcanic ash noticeable in seams nearer the surface is relatively small indicating lesser interference from volcanic eruptions during recent periods. The present vegetation on the surface of the underent muskeg consists of black spruce, birch, and small cushions of sphagnum mosses dominated by several species of heath shrubs.

muskegs examined are underlain with calcareous marl which has potential value for local domestic use as lime in the improvement of agricultural soils and in the manufacture of Portland cement. A representative type of these muskegs is at Wasilla Lake. It is located in section 1 of T. 17 N., R. 1 W., about 60 feet south of a graded road that passes through Palmer and Wasilla.

The water of the lake has a reaction of pH 8.0 and is clear to a depth of about 4 feet; below this the water is filled with grey deposit of Chara marl which extends to a depth of 12 feet and rests on sandy gravel. Tests of the marl show a strong reaction for carbonates with dilute hydrochloric acid. Near the border are aquatic plants among which species of *Potamogeton* and *Myriophyllum* are abundant, but *Chara* is rare; at the margin of the lake, the closely standing culms of *Carex* and *Scirpus* with *Menyanthes trifoliata* form a narrow fringe reaching out with their rhizomes to deeper water.

The banks of the muskeg, which are about 1½ to 2 feet above the water, give evidence of being afloat. Soundings taken along the border indicate that a layer of peat 4 feet in thickness, is underlain by marl. The floor is uneven but the average depth at which sandy gravel is reached below the surface is 12 to 13 feet.

Throughout the muskeg are signs that changes are taking place at the surface--either retrogression or transition. Cushions and hummocks of sphagnum mosses, pH 4.3 in reaction, show patches of *Polytrichum*, *Hypnum*, and blue-green algae. *Ledum* and other heaths are being replaced by a number of deciduous shrubs, the most noticeable of which are bushy willows (*Salix* spp.) and species of *Ribes* and *Rosa*. The general surface shows *Myrica gale*, *Potentilla fruticosa* and *Vaccinium vitis-idaea* var. *minus* but they might be regarded as part of the flora which formerly covered the muskeg. The vegetation is dominated by sedges and grasses and characterized by the following species in an order of abundance which, however, is not always the same: *Calamagrostis*, *Scirpus*, *Carex*, *Eleocharis*, *Festuca*, and *Galium*. The contrast of this form of vegetation with the plants found on typical muskegs is striking and accentuated by the transitions from shrub to marsh and sphagnum moss bog communities. It is not known to what extent fire or drainage should be considered as factors in retrogression stages.

Profile sections made in places adjacent to hummocks of sphagnum mosses and near the margin of the lake give the following record:

0–42 inches; the upper 6 inches consist of light reddish-brown sphagnum moss peat, spongy fibrous in texture, acid and relatively free from woody material; it grades into a mixture of brown moss and sedge peat which contains roots and rhizomes of the growing vegetation from the 10- to 18-inch level; the material rests on a thin seam of volcanic ash; below it, is reddish-brown sphagnum moss peat to a depth of 38 inches below the surface, which contains the matted network of roots and rhizomes from tussocky sedges; near the fourth foot level is a layer of dark brown woody sege peat with stumps of spruce and birch on marl.

42–108 inches; gray *Chara* marl; yellow-tinted to pink in color at lower levels; at the base it merges into brown organic sediments, about 2 to 3 inches thick and derived from aquatic plants and plankton organisms.

108–110 inches; sandy gravel.

The profile features described strongly suggest changes during the development of the muskeg similar in character to those observed in the Palmer muskeg. The nature of the marl indicates the presence of an early lake and a primary free-floating aquatic vegetation which was soon replaced by species of *Chara* and probably certain blue-green algae; they are the chief agents responsible for the great precipitation of lime over the floor of the lake. Thereafter trees of spruce and birch with their associates appeared over the surface of the marl, indicating a change to drier conditions. This was followed by a cool, moist period associated with the active growth and spreading of sphagnum mosses and sedges. The salient features of interest in such changes have been described on pages 32 and 68.

WILLOW (NO. 37)

Three-tenths of a mile north of Willow, on a graded road, is a winding channel resembling a series of pondlike depressions in a flat plain. The vegetation of the open water has several aquatic mosses (*Hypnaceae*) with *Potentilla palustris*, *Menyanthes trifoliata*, and a growth of waterlillies. The pond margins are colonized by a stand of sedges, nowhere flowering but probably *Carex aquatilis*, *C. limosa*, and *C. rostrata*, which grow tall and rank, forming quaking mats as they advance over the water with their spreading roots and stolons. In less wet places are low thickets of willow, alder, birch, and heaths with patches of sphagnum mosses. Profile soundings agree in showing a depth of 13 inches of brown fibrous matted sedge peat which contains an admixture of moss peat; the material is underlain by coarse sandy gravel.

Further on along the graded road, nearly 3.5 miles northeast of Willow, the areas of tall sedges with their ground cover of sphagnum mosses give way to muskegs in which dwarfed black spruce is the characteristic tree. The basis of the muskeg is a hummocky growth of sphagnum colonized by other vegetation as the accumulation of peat is built up. There is a large variety of shrubs including *Betula glandulosa*, *Myrica gale*, *Potentilla fruticosa*, *Andromeda polifolia*, *Chamaedaphne calyculata*, and *Spirea* sp. The shrubby undergrowth does not make any large fraction of the surface vegetation but it gives the aspect of a heath transitional in the development of a flat muskeg. Fluctuations of water level may be the factor inhibiting the growth of herbaceous plants.

The hummocks of sphagnum mosses between shrubby thickets are capped with *Empetrum nigrum*, *Vaccinium vitis-idaea* var. *minus*, *V. oxycoccus*, *Drosera rotundifolia* and others. In the intervening hollows are species of *Eriophorum*, *Carex*, and *Equisetum*. Scrubby, spindle-shaped black spruce with a superficial root system occur to a varying extent over most of the muskeg. Although the trees are relatively small, they seem to have persisted for some time, but stumps were not found in the layers of peat below the surface. The general depth of peat in the muskeg ranges between 3 and 4 feet and the underlying mineral material is silt on fine gravel.

The salient features of vertical soundings are as follows:

0–3½ feet; mixture of moss and sedge peat, brown, fibrous, typically matted in the upper 6 inches; the material below it consists of 2 inches of dark brown, partly decomposed moss and sedge peat on which are resting roots of woody shrubs; this shades into compacted brown, fibrous sedge peat containing flattened rhizomes of *Scirpus* and *Eriophorum;* the layer extends to the third foot level where it merges with 6 to 8 inches of dark brown organic sediments derived from aquatic plants.

3½–4 feet; transition to silty organic residue, brown in color, on silt over fine gravel.

All such evidence indicates comparative youth of the local muskeg; its history is much the same as that of similar muskegs elsewhere in this district. The facts at hand are not sufficient, however, to determine approximately the time that has elapsed since the muskeg began its development and formation on the silt and gravel. The advance of vegetation in its successional stages and an approximation of the conditions existing at earlier times have been among the principal subjects of peat investigations in the territory. It remains for future observations to determine the rate of accumulation of peat material and to discover the length of time since the surface of mineral soils became exposed upon which muskegs are in process of active development in a changing environment. How much further the changes in surface vegetation are going, cannot be stated. It is entirely possible, however, that the present stages in muskeg development are only a forerunner of a type of forest closely adjusted to the conditions of the climatic climax of the region.

PEAT RESOURCES IN INTERIOR ALASKA

The main topographic features of interior Alaska correspond in a broad way to a central plateau. For the most part this region is a gently rolling upland broken by a number of rounded domes and mountain groups, and diversified by many broad valleys. It is drained into Bering Sea by the Kuskokwim, Tanana, Yukon, and other rivers and their tributaries, and includes a number of lowland areas of considerable extent covered in places with muskegs.

The greater part of the upland has an average elevation of 300 feet and seldom rises to more than 600 feet. It supports forests of open woodland types which are largely confined to the valley floors and the lowest slopes of ridges. The stands are mixtures of spruce and birch. Cottonwood groves are frequently seen along the larger streams and tamarack also grows in this region. In the main the trees are too small to be commercial timber but are highly important for big game and fur bearers. Over large areas the ground remains permanently frozen; during summers it thaws to shallow depth only, ranging from 20 to 50 inches below the surface.

The climate is continental in type. Precipitation is small, varying locally from 10 to 16 inches a year, of which approximately one-half comes during the growing season. The winters are long and cold, the temperature averaging less than $-20°$ for January and often dropping to below the minimum of $-66°$ for continental United States. The annual snowfall varies from 3 to 8 feet. The summers are short and warm with a growing season from 80 to 90 days. It is quite generally the opinion among older residents of the country that present-day methods of hydraulic mining have reduced the flow of creeks and lowered ground-water levels.

The climate is generally such as to favor agricultural possibilities of the land. The prolonged daylight in summer enables grain crops to make rapid growth, and vegetables like cabbage, celery, and lettuce attain large size during the short season even well within the Arctic Circle. The principal area available for agricultural settlement is the Tanana Valley. Information regarding soils has been published by Bennett and Rice (*3*) and publications giving the results of agricultural experiments are issued by the College of Agriculture of the

University of Alaska (*17*). The most important farm crops are grains, root crops, and potatoes. Oats and barley are grown both for grain and forage. Pasture is available for 4 months of the year and the Tanana region is well suited to dairying and for the production of hogs. Gardening is successful in nearly every town and in several outlying districts, and a variety of edible wild berries can be gathered in many places.

Fairbanks is the principal city of the interior and the seat of the University of Alaska. It is located almost exactly in the geographical center of Alaska. As a focal point of transportation, it is the northern terminus of the Alaska Railroad, the Richardson Highway, the Steese Highway —and of various air routes.

Muskegs of the Mount McKinley Range

This district lies on the south flank of the Alaska Range and includes the southeast side of Mount McKinley (Mount Denali). It has been described in reports by Tuck (*38*), Capps (*6*) and Moffit (*28*). The relief of the area ranges in elevation from 500 feet along the Chulitna River to 20,300 feet at Mount McKinley. Practically the entire district, with the exception of the higher peaks and ridges, has been glaciated. The Susitna River and its tributary, the Chulitna, flow in broad valleys and drain the larger part of the district. The Alaska Railroad follows the east bank of the Susitna River and most of the muskegs in the valley and on the pass can be easily reached from points along the railroad.

HURRICANE (NO. 38)

Between mile 283 and 284 on the Alaska Railroad are gravel and rock walls, several hundred feet above the Chulitna River. The location is not far from Hurricane Gulch. In constructing the roadbed a cut was made which extends practically through the entire length of a muskeg. The depression which the muskeg occupies is concave but narrow, and its depth in the central portion averages 10 feet. The glacial material at the base is sandy gravel which has an uneven surface and contains organic residues.

Scattered stunted black spruce (*Picea mariana*), and dwarf birch (*Betula glandulosa*), low shrubs of *Ledum groenlandicum*, *Andromeda polifolia*, *Kalmia glauca*, *Potentilla fruticosa*, and *Vaccinium uliginosum*, in a ground cover of sphagnum mosses in hummocks nearly a foot in diameter and 8 inches high, with their associates *Empetrum nigrum*, sundew, cranberry, and tussocky sedges (*Scirpus caespitosus*, *Eriophorum* sp.) give a floristic aspect to the muskeg. In burned-over openings are fireweed (*Chamaeneriore angustifolium*), reedgrass (*Calamagrostis* sp.), a few anemones, gentians, and aster.

On the east side of the railroad bed, the cut exposes the shallower margins of the muskeg. The material consists generally of conifer debris partially decomposed, more or less embedded in crumbly woody peat averaging 4 feet in thickness. It contains two superposed layers of stumps and roots of spruce and birch, which are separated by a seam of grayish white volcanic ash ranging between 3½ and 6 inches in thickness. The reaction of the woody peat is pH 4.5 and that of the volcanic ash is pH 5.8 to 6.0.

Exposures along the west side of the cut reveal an upper layer of brown, fibrous sedge peat which is felty-matted in places. It averages a thickness of 6 to 7 feet and has a reaction of pH 5.5. At the surface are 3 to 4 inches of spongy-fibered sphagnum moss peat strongly acid in reaction; near the 4-foot level below the surface is an intercalated 3-inch seam of volcanic ash which is doubtless of the same age as the layer of ash along the eastern margin of the muskeg. Below the sedge is yellowish brown, well-preserved, somewhat laminated hypnum peat ranging from 2 to 5 feet in thickness. It is to be noted that both sedge and hypnum peat form a thicker layer in the deeper portions of the muskeg. The layer of hypnum peat is free from volcanic ash but it contains at the lower level plant remains representing various sedges and aquatic vegetation.

From the facts stated above it appears that the depression may have been for a time a water basin which supported floating mats of *Hypnaceae* and pond weeds. It was later tenanted by sedges and particularly by trees on the slopes facing the west. Sphagnum mosses have dominated the muskeg only within relatively recent times.

BROAD PASS (NO. 39)

The approach to Broad Pass from Hurricane Gulch is a more or less gradual ascent. The pass itself is described by Moffitt (*28*) as a gravel-floored flat several miles wide, at an elevation of about 2,350 feet above sea level. It is drained primarily by Nenana and Chulitna Rivers and near it is Summit Lake, which marks a watershed draining both to the Bering Sea and the Pacific, i. e., between Cook Inlet and the Yukon River.

The region is near the timber line. The muskegs have a scattered and scrubby growth of spruce and much of the undergrowth and ground cover is not unlike that encountered farther south. Willows and alder occur along the small tributary creeks, while grasses as well as sedges are relatively more abundant in wetter portions of the muskegs, the latter forming characteristic tussocks that are raised above the water level.

Profile soundings agree in showing a brown, felty-fibered and closely matted sedge peat, averaging 3½ feet in thickness, underlain by greenish-blue sandy gravel. At the surface, the layer contains an admixture of sphagnum moss peat, and at a depth of 2 feet below the surface, is a thin bed of gray volcanic ash of clayey consistence.

THOROFARE PASS (NO. 40)

The highway within the eastern portion of Mount McKinley National Park crosses open mountain valleys, slopes of foothills, and several mountain passes at an altitude of 3,000 feet or more above sea level. A spur, 1½ miles in length, connects the main highway with Wonder Lake.

Muskegs were observed on the passes, especially between Thorofare Pass and Wonder Lake, but were studied hastily only in passing. They are small in areal extent and show a matlike growth characteristic of high mountain altitudes and the rigors of the climate. Spruces and heath shrubs, such as *Ledum* and *Andromeda*, have a relatively smaller part in the floristic composition of the surface vegetation than tussocky sedges and the low cushions of sphagnum mosses on which are found *Empetrum nigrum* and several herbaceous associates. Transitions lead to alpine vegetation having a foothold in stony ground and loose rock talus. An examination of any particular transitional stage that passes into muskeg reveals lack of definiteness in the type of plant communities. A number of plants such as *Betula glandulosa*, *Empetrum*, *Vaccinium* and *Eriophorum* are indifferent to a peaty habitat; they intermingle with the small clumps, rosettes, and carpets formed by species of *Saxifraga*, *Dryas*, *Arctostaphylos*, *Silene*, and others which find their most characteristic development on the bare stony ground.

Profile samples obtained in different places show that the peat has been accumulated chiefly by sedges and that hypnum mosses accompanied them in the early stages of muskeg development. The material is brown, matted-fibrous, pH 5.0 in reaction, and the thickness of the layer averages 2 feet, probably representing a considerable length of time at those high altitudes and short growing seasons. The sedge peat is underlain by sandy gravel over stony gravel.

An enumeration was made of the plants on muskegs which occur in depressions on talus sloping to McKinley River. It gives a good indication of the degree of local variation. The list includes *Potentilla fruticosa*, *Rubus chamaemorus*, *Cornus canadensis*, *Vaccinium uliginosum* var. *alpinum*, and species of *Delphinium*, *Pedicularis*, *Artemisia*, and *Valeriana*. As a rule the plants have a meager root system which is mainly superficial, although exceptions were noted where the development of roots is fairly large.

In the flats on McKinley River, shallow pools of water were examined which are fed by springs and give a mildly alkaline reaction (pH 8.0). Along the margins a calcareous crust and granules of marl formed by blue-green algae cover stones as well as aquatic plants, mainly *Hypnaceae* and a species of *Potamogeton*. The layer of marl is thin, rarely exceeding 2 or 3 inches in thickness.

MUSKEGS OF THE FAIRBANKS DISTRICT

The Fairbanks district forms part of the semiarid central plateau of Alaska. Prindle (*32*) recognizes three topographic divisions: The Tanana lowland which merges with the foothills of the Alaska Range; the upland north of the Tanana valley, and the Yukon lowland. The mean altitude of the valley floors is from 400 to 800 feet and that of the upland and summits in the Sawtooth Mountains from 1,500 to 3,000 feet above sea level.

The Tanana lowland is a broad flat which widens toward the Yukon. It is more or less timbered and contains muskegs and lakes some of which are the remnants of former watercourses.

The dominant topographic features of the upland north of the Tanana are slightly rounded, domelike ridges separated in most of the area by comparatively narrow, closely-spaced valleys. Some of the valley floors have muskegs.

The Yukon flats include many meandering streams with lakes and muskegs. Near the water courses the flats are timbered and the trees grow to considerable size. Among the most characteristic and generally distributed trees in the Fairbanks district are spruce, birch, poplar, and tamarack. The smaller streams are often bordered by willow and alder, and the muskegs have a ground cover of sphagnum mosses in which cottongrass, sedges, blueberries, cranberries, and others are locally abundant. Sphagnum mosses have been utilized for stopping leaks in dams and ditches and for roofing and chinking log cabins, sluice boxes, and mine shafts. The hydraulic methods, practiced in the region to work gold-bearing gravels have greatly accelerated the destruction of muskegs.

FAIRBANKS (NO. 41)

Fairbanks is situated on Chena Slough, a channel of Tanana River. Northwest of it, between the university farm and the city, is a muskeg located in section 33 of T. 1 N., R. 1 W., about 1½ miles from the Alaska Railroad at College, Alaska. A graded road crosses the muskeg at its southern end.

FIGURE 21.—Test pit dug several years ago in muskeg near the University at Fairbanks; an early attempt at commercial exploitation. It is now filled with water and supports floating mats of cottongrass and sphagnum mosses.

The muskeg comprises over 400 acres and occupies a basinlike depression. The vegetation is essentially similar to that of the muskegs in the valleys north of Fairbanks but the relative abundance differs and the chief feature of interest in this area is the presence of tamarack as well as spruce. The whole muskeg, and particularly the more central portion, is dominated by actively growing sphagnum mosses (*Sphagnum medium*, *S. fuscum*, *S. rubrum*, and others), which form hummocks about 1½ feet above the intervening hollows. In the outer marginal portions several sedges are prominent, and the sphagnum mosses decrease in amount. The stand of spruce is thicker and usually with an undergrowth of heaths which can bear moderate shading and a lower water level. The taller trees and heaths fringe the shallower margins. In the more open center, the plants characteristic of the ground cover on the wetter hummocks include *Vaccinium vitis-idaea* var. *minus*, *Rubus chamaemorus*, cranberry, and sundew. The somewhat drier hummocks support *Ledum groenlandicum*, *Chamaedaphne calyculata*, *Andromeda polifolia*, *Betula glandulosa*, several blueberries, and occasionally a seedling of tamarack and spruce. Subordinate species are cottongrass (*Eriophorum* sp.) and lichens. Very little zonation of the vegetation is to be seen but as the center of the muskeg is approached, the tree growth is more dwarfed and scattered and hummocks of sphagnum mosses become relatively more abundant.

A test pit dug several years ago, now filled with water and supporting quaking mats of cottongrass and sphagnum mosses (fig. 21) did not reach bottom. It disclosed that the muskeg is frozen below the surface with the exception of a few inches of surface thaw during the summer months. Profile soundings made near the test pit and at several other points show the following:

0–3¼ feet; sphagnum moss peat; the typical color is reddish-brown, the structure is spongy fibrous, and the reaction pH 4.0; a variant is yellowish-brown material near the 2-foot level which contains an inclusion of volcanic ash and an admixture of roots and rhizomes of sedges.

3¼–4 feet; woody sedge peat, dark brown in color and more or less crumbly; most of the layer is composed of woody fragments derived from shrubby heaths and conifers; flat-rooted stumps occur near the 3-foot level.

4–6 feet; moss and sedge peat; the upper portion of the layer contains small amounts of woody material, is reddish-brown in color and somewhat decomposed; below it, the material is fibrous matted moss and sedge peat; some of it shows plant remains from *Hypnaceae*; at the lower level the material is in a frozen condition, preventing further soundings.

It should be emphasized that the profile section, described above, does not represent layers or peat material at equal depths elsewhere in this muskeg. The exposures of muskegs in the Goldstream Valley and at Fox exhibit a thickness of moss peat and profile features that may not be uncommon in this area. Sphagnum mosses have characterized the recent stages of muskeg development and might be expected to have contributed more extensive and thicker layers of moss peat than observed so far in the Fairbanks muskeg. The plant remains which comprise a layer of peat, the quality or purity of the peat materials, as well as the structural sequence of the separate layers depend largely upon the particular environmental conditions of the stream valley, notably upon the water supply and the relief of the underlying mineral substratum upon which the muskeg began to develop. Further investigation of profile features in this area is very desirable for an understanding of important ecological relationships and industrial possibilities. It is evident that experience and familiarity with the principles of the process of muskeg formation will aid in recognizing inherent differences and locating areas of peat that have commercial value.

GOLDSTREAM (NO. 42)

In the Fairbanks district muskegs are not uncommon in the stream valleys that are productive of placer gold mining. Fox Valley, Goldstream Valley, the valley of Engineer Creek, Ester Creek, and others in the vicinity of Fairbanks are of this character. A map of their general distribution is shown in the report by Hill (*21*). Most of them are solidly frozen and open-cut methods of mining are applied where conditions are particularly favorable for using hydraulic equipment (fig. 22, A). The material exposed by these mining excavations includes various kinds of peat and underlying beds of clay, silt, sand, and gravel deposited under conditions predominantly alluvial, but in part also lacustrine. Prindle (32) cites the following example as a

FIGURE 22.—Placer gold mining with hydraulic equipment in valleys excavated near Fairbanks has revealed: A, stratified layers of ice, silt, gravel, and volcanic ash, and frozen mucks at different levels below the surface; B, fossils of animals from prehistoric periods. Fossils collected by W. L. Geist of the University of Alaska.

record of superimposed beds in a columnar section of Dome Creek Valley:

	Depth (feet)		Depth (feet)
Muck	6	Ice	11
Ice	9	Muck	44
Muck	12	Gravel	35

A more detailed observation of sections examined during this investigation shows layers of ice which contain thin layers of stratified gravel or sand and are capped by several feet of gravel; beds of volcanic ash varying in thickness; and deposits of peat alternating with thick layers of silty organic residue to which the term "muck" is applied by miners. The noteworthy characteristics of the valley deposits are the great depth of material, generally ranging from 80 to 250 feet in the larger and wider valleys, their consolidation by ice, the strong "bituminous" odor of the organic matter, and the teeth, tusks, and bones of mammoth, mastodon, elk, and other extinct animals that are frequently found at lower levels in the alluvial material overlying bedrock. Representative fossils are in the collections of the University of Alaska Museum and in the American Museum of Natural History in New York (fig. 22, *B*).

The Goldstream Valley may fairly be considered an average example, and its history may have been much the same as that of similar valleys in this district. Sections exposed there indicate at least four superimposed muskegs which developed during successive (interglacial?) periods.

The earliest peat formation developed over the gold-bearing gravel on bedrock. The material consists of coarsely fibered sedge peat, in places showing stumps of spruce and birch with sphagnum mosses; it is generally overlain by ice. A typical cross section of the second deposit of peat, some 12 to 15 feet above the base, is composed of woody sedge peat in an advanced degree of alteration, with two to three layers of stumps and roots of spruce and birch, woody fragments from heath shrubs, and patches of sphagnum mosses; it is usually capped by sand and gravel. Approximately 10 to 12 feet below the present surface is a third stage of peat formation. The material is mainly fibrous, tussocky sedge peat which in its upper portion contains woody material, an admixture of *Hypnum*, *Polytrichum*, and plant remains from sphagnum mosses; it overlies silt on gravel and is covered with silt or stratified silty organic residue. On the surface back from the eroding bluff is the muskeg of recent age but much disturbed by the mining operations.

A short distance from the highway and about 2 miles west of the town of Fox, a few remnants of a muskeg were examined which, before the removal of the overburden, extended across a large portion of Goldstream Valley.

The vegetation, history, and changes in conditions that must have characterized the muskeg during the recent period of its development are shown in the following profile features:

0–3¼ feet; spaghnum moss peat; for the first 10 inches the material is light brown, grayish tinted, compact and slightly decomposed; the next 15 inches are yellow brown in color, spongy fibrous, and shade into moss peat which contains woody material from various shrubby heaths.

3¼–4¼ feet; woody sedge peat; the upper portion contains coarse fibrous tussocky material from cottongrass and sedges; near the 4-foot level are stumps of spruce rooted in dark-brown woody peat.

4¼–6 feet; sphagnum moss peat; yellow brown, spongy fibrous in a more or less frozen condition and flaky in structure; it contains small leafy fragments and woody material derived chiefly from heath shrubs.

6–8 feet; sedge and hypnum peat;[5] yellow brown in color, laminated; at the lower level the plant remains are compact and consist of *Hypnaceae*, well preserved and relatively free from rhizomes and roots of sedges.

8–9 feet; woody peat; dark brown in color, contains needles, leaves, and loose woody material from conifers and heath shrub; merges more or less sharply into gray volcanic ash over silt.

FOX (NO. 43)

Another locality at which muskegs are well developed is the terrace deposit bordering Goldstream Valley and Ester Creek. The fact that they are fairly undisturbed and were observed at several other localities indicates the need for more detailed peat investigations throughout the district.

In section 31, T. 2 N., R. 1 E., mining excavations have exposed the front of a terrace directly east of Fox near the mouth of Fox Gulch. The material observed in the vertical cross section consists of gravel overlaid by micaceous silt and mantled by peat 7 to 8 feet in thickness.

The surface vegetation resembles that of the Fairbanks muskeg. It consists of a border of tussocky sedges varying in width. The central portion of the muskeg is composed of small irregular hummocks of sphagnum mosses on which grow *Empetrum nigrum*, *Vaccinium vitis-idaea* var. *minus*, *Rubus chamaemorus*, cranberry, sundew, and patches of *Polytrichum* sp. The dominant heaths are *Ledum groenlandicum* and various blueberries. Birch is represented by occasional, isolated, low-growing plants of *Betula glandulosa*, and the few conifers are dwarfed forms of spruce associated with tamarack.

A typical cross section exposed in the cut bank of the terrace deposit shows the following:

0–34 inches; sphagnum moss peat, straw-colored shading to yellow brown, spongy-fibrous, relatively free from woody material and rhizomes, compact and distinctly laminated at the lower level.

34–37 inches; small stumps of spruce and flat-based roots of spruce in dark brown moderately decomposed moss peat; contains an admixture of woody material from heath shrubs.

37–80 inches; sphagnum moss peat, reddish brown in color, more or less compact and laminated; flaky when dry; below the 6-foot level the material contains small amounts of rhizomes and rootlets from cottongrass and woody roots from heaths.

80–92 inches; sedge peat, gray brown in color, fibrous matted, composed in large part of well-preserved sheaths and flat, jointed rhizomes of tussocky sedges.

92–95 inches; woody peat, dark reddish brown in color, crumbly; contains bark of birch and spruce, needles, leaves, and woody material from ericaceous shrubs, roots, and stumps of spruce; at the base, the woody peat merges with a thin layer of coarse fibrous sedge peat; root channels extend into the underlying mineral substratum.

95 inches; gray, micaceous silt finely stratified, probably deposited during lacustrine conditions or by stream action.

It seems clear from the profile features described that the mineral and organic deposits in the valleys of this region have great scientific interest. The district has not been exposed to direct glaciation. Deposition of materials in the valleys began, doubtless, in the early

[5] Hypnum peat is best developed in the Yukon flats where muskegs occupy shallow depressions. Material collected by Sam O. White of the Alaska Game Commission, and taken at different levels from a muskeg exposed on the steeper sides of the open flat valley about 1 mile northwest of Circle, indicates that plant remains from *Hypnaceae* predominate in all levels and extend down continuously from the surface to within a few inches of the dark gray micaceous fine sand about 5 feet below. The material from the 2- to 5-foot level contains rhizomes and rootlets from sedges with silt probably from flood stages of the river.

stages of the Pleistocene and continued to the present time. Conditions were somewhat different from those now prevailing. Of particular interest is the frozen condition, known to exist also in northern Canada and which has been described by Nikiforoff (*30*) for northern Asia. The excavations in the valleys offer a unique opportunity for a study of the history of this region; the sequence of events connected with periods of more abundant precipitation and active erosion, followed by periods of peat accumulation; changes in elevation, in climatic conditions, and in the movement and development of fauna and flora. The valley deposits contain invaluable and continuous records dating back into the prehistoric past and include bones of extinct animal life and the plant remains of interglacial peat deposits. There are, evidently, clues to aid in determining how many of the major glacial stages of the Pleistocene the valleys represent, and whether the profile sections of more recent muskegs record advances and retreats of the last glaciation, or substages of an interglacial period (p. 28), rather than alternating cold and warm epochs. It seems probable also that the layers of volcanic ash in muskegs are very nearly contemporaneous. They may serve, therefore, as a means of correlating profile features of muskegs in this region and aid in locating the volcanoes that produced the ash in these deposits. At present many of the valleys are rapidly being destroyed and great stretches are now bare, stony valley floors. It is hoped that at least portions of some of the valleys may be set aside as a reserve for scientific investigations.

SUGGESTIONS FOR COMMERCIAL UTILIZATION OF PEAT RESOURCES IN ALASKA

In the earlier part of this report the subject of muskegs has been considered from several viewpoints. Stratification or arrangement of peat layers below the surface is the most distinctive structural feature; it arises from differences in plant remains that accumulated under changing conditions of environment. The character of the peat-forming vegetation and the influence of climate and topography, mineral substratum, and ground water nutrients that constitute the environment are the more important factors in the extensive development of muskegs and in their classification.

A large proportion of muskegs are located along the shores of islands and the mainland. Those developed on seaward slopes and valley flats, are relatively accessible, and are capable of serving as a source of humus-forming organic material for the continental United States. Of special significance are layers of sedge peat and sphagnum moss peat. The possible thickness of these layers ranges from 4 to more than 6 feet. What quantity can be supplied by the territory is still problematical. The data in hand are too inadequate to form the basis for any close estimate but it cannot be doubted that the reserves are large.

Under present circumstances, a basis for broad consideration of the uses of the territory's peat resources is lacking. The possibility of establishing a local small-scale peat industry seems definitely favorable at this time. But the difficulties affecting the economy of Alaska are the highly seasonal industries operating for short periods in summer in areas with a sparse population. This gives rise to special problems in transportation and planning (*41*). It requires the continuing transfer of labor from seasonal activities to some other form of seasonal employment. If a peat industry holds out a new prospect of employment, then it is desirable to make a more thorough survey and study of the problem than the time at the disposal of the writer permitted.

The development of a peat industry in Alaska must inevitably be by a series of steps. To aid in this exploitation, it would be well to point out what has been done in the past and is now in progress along those lines. In the following, it is not the intention to enter into technical or theoretical phases bearing on a plan for the development of peat resources, except to point out that a practical working method capable of commercial operation and reducing the cost of production is an essential preliminary step toward the establishment of a peat industry in Alaska or continental United States.

Importance of Commercial Peat Production

The commercial production of peat in continental United States has fluctuated from year to year (fig. 23), but the trend upward has been

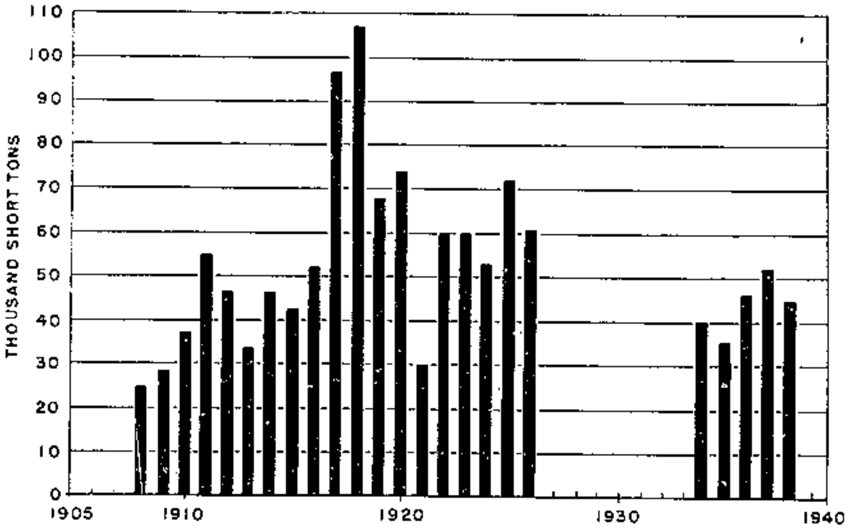

Figure 23.—Development of domestic peat industry in continental United States during 1908–38, based on reports of the United States Bureau of Mines (*39*)

greater in recent years than at any time in the past. The domestic production of peat first attained commercial importance in 1908. A peak was reached during the World War in 1917 and 1918.

The quantity and value of the output in recent years, and of the annual supply of peat that is being imported, are given in table 1. It should, however, be borne in mind that the figures on domestic production are not complete. They do not represent the total production of peat in the United States or the different kinds of peat material marketed, and they do not take into consideration the many small producers as well as municipalities which operate plants for local use. The steps taken toward standardizing grades of peat in this country indicate a growing knowledge regarding the commodity and an appreciation of the value of selected products for use as organic soil amendments and for various other purposes for which the demand is increasing.

TABLE 1.—*Quantity and value of peat produced in the United States* [1] *and imported,*[2] *1915–39*

Year	Quantity produced in the United States	Quantity imported	Value of domestic production in the United States	Value of imports
	Short tons	*Short tons*		
1915	42,284		$288,537	
1916	52,506		369,104	
1917	97,363		709,900	
1918	107,261		1,047,243	
1919	69,197	464	705,532	$16,345
1920	73,204	2,762	921,732	30,201
1921	30,406	3,450	260,119	22,754
1922	60,680	4,805	397,729	33,034
1923	61,355	5,973	376,834	43,184
1924	55,469	5,541	395,470	47,208
1925	72,436	10,233	452,898	121,719
1926	61,936	16,669	364,413	174,241
1927		31,595		326,549
1928		40,087		422,275
1929		57,531		657,145
1930		70,466		869,381
1931		63,928		682,553
1932		64,701		601,372
1933		41,217		442,766
1934	40,544	44,132	214,185	547,353
1935	37,060	54,547	199,377	677,513
1936	46,126	75,066	266,863	955,807
1937	51,223	86,871	305,126	1,219,127
1938	45,933	69,509	286,127	1,092,942
1939	55,483	78,611	362,066	1,204,883

[1] From compilations by the U. S. Geological Survey and the Bureau of Mines. Data for 1927–33 not available.
[2] From compilations by the Bureau of Mines. No imports previous to 1919.

Relatively few States as yet produce the larger part of the total for the United States. Reports covering the production of peat in 1939 were received by the Bureau of Mines from 39 producers operating in 15 States. The distribution of producing plants indicates that existing operations are determined largely by the scope of the regional market but limited by the geographical location of the peat area and the degree of skill employed in selection and preparation of the peat material. New Jersey and New York were the leading producing States in 1939. Other States, in the order of quantity of output reported, were Michigan, California, Florida, Colorado, Ohio, Minnesota, Iowa, Washington, Pennsylvania, Maine, New Hampshire, and Massachusetts,

IMPORTS BY FOREIGN COUNTRIES

Imports of moss peat first began in 1919 and have increased steadily in recent years. The annual supply of foreign moss peat has been mainly from Europe and to a lesser extent from Canada and Japan. A glance at table 2 will show that Germany and Sweden supplied the larger quantity of the material, that the average value per ton has been rising, and that the total value of imports of moss peat has passed the million dollar mark. The Bureau of Mines (*39*) reports that, of the total imports, approximately 62 percent was received in 1937 through customs districts at Atlantic ports, 21 percent at Gulf ports, 16 percent at Pacific coast ports, and 1 percent at Canadian border ports of entry.

TABLE 2.—*Peat moss imported for consumption in the United States, 1937–38, by countries*

Country	Imports in 1937		Imports in 1938	
	Quantity	Value	Quantity	Value
	Short tons		*Short tons*	
Belgium	323	$6,024		
Canada	2,974	68,730	3,989	$91,167
Denmark	1,000	16,839	1,239	17,293
Estonia	1,139	20,018	1,486	26,514
Finland			77	1,659
Germany	52,928	630,218	36,381	525,564
Japan	83	1,701		
Latvia	1,414	23,582	1,604	31,166
Netherlands	5,018	65,501	6,709	65,968
Norway	968	18,604	744	13,325
Poland and Danzig			222	3,145
Sweden	19,058	338,962	15,127	282,284
U. S. S. R. (Russia)	1,250	17,918	1,433	25,455
United Kingdom	707	11,030	498	6,402
Total	86,871	1,219,127	69,509	1,092,942

STANDARDS AND SPECIFICATIONS FOR COMMERCIAL PEAT PRODUCTS

As an initial step toward standardizing the various kinds of peat now placed on the market, attempts were made several years ago to distinguish between the commercial peat products with respect to botanical composition as well as to physical and chemical properties and value for soil improvement (*12*). Of great importance to the peat industry is the fact that the Treasury Department, through its Procurement Division, has adopted standards for grades of a number of distinct types of peat recognized commercially and has issued specifications and proposals to cover the purchase of three kinds of humus-forming peat material required by the Federal Government. Standards have been set up in order that in the event of an emergency, quantity production will not be delayed by lack of information, and that operating plants may produce a uniform quality of peat material when and where needed.

The standardization of peat products implies the selection of a few types that are most suitable for the purposes desired. Specifications, on the other hand, are concerned with a description of the characteristics of the type of peat to be procured. It is evident that the peat industry can largely influence the work of standardization by cooperating with the respective Federal agencies. Even those producers and dealers who are not interested in procuring Government contracts should familiarize themselves with the specifications for the grades of peat produced in this country and they should be bound by these specifications in all work pertaining to soil improvement.

The following schedule, specifying price, unit, and time of delivery, has been adopted tentatively by the Procurement Division of the Treasury Department for supplies of peat materials which the Government purchases for use by Federal departments and other establishments:

	Price	Unit	Time of delivery
Moss litter:			
Sphagnum moss; light grayish green, whitish, or pinkish colored, undecomposed, well air-dried, derived or gathered from surface growth of sphagnum mosses; free from pine needles, twigs of woody shrubs, and other impurities; acid reaction varying between pH 4.0 and 5.0, water-absorbing capacity ranging from 1,100 to 2,100 percent; shall contain approximately 30 percent moisture by weight on oven-dried basis; 3-pound sample required:			
(1) By the bale			
(2) By the 10 bales			
(3) By the carload; state approximate number of bales to carload			
Peat:			
Moss (Sphagnum) peat; brown; acid reaction approximately 4 to 5 pH; free of wood material, and mineral matter such as sulfur and iron; in air-dry condition; water-absorbing capacity varying from 1,100 to 2,000 percent; shall contain approximately 35 percent moisture by weight on oven-dried basis; if satisfactory in other respects, moisture content in excess of 35 percent may be accepted, but settlement will be made on weights corrected to 35 percent moisture basis; bidder should state approximate number of pounds to bale; 5-pound sample required:			
Horticultural grade; granulated or shredded:			
(1) By the bale			
(2) By the 10 bales			
(3) By the carload; state approximate number of bales to carload			
Poultry litter grade:			
(1) By the bale			
(2) By the 10 bales			
Stable bedding:			
(1) By the bale			
(2) By the 10 bales			
(3) By the carload; state approximate number of bales to carload			
Reed peat or sedge peat; brown; fibrous, shredded coarse or fine; low ash content (5 to 10 percent); low in mineral material such as iron and sulfur; low in content of woody material; water-absorbing capacity ranging from 350 to 800 percent; water content not to exceed 45 percent by weight on oven-dried basis; if satisfactory in other respects, moisture content in excess of 45 percent may be accepted, but settlement will be made on basis of weights corrected to 45 percent moisture content; 5-pound samples required:			
Acid grade; reaction may vary from 4.5 to 5.5 pH:			
(1) By the 100-pound bag or 200-pound bale or box			

	Price	Unit	Time of delivery
Peat—Continued.			
Reed peat or sledge peat—Continued.			
Acid grade—Continued.			
(2) By the ton (2,000 pounds); in 100-pound bags or 200-pound bales or boxes			
(3) By the carload: loose bulk; state approximate number of pounds or cubic yards per ton to carload			
Slightly acid to slightly alkaline grade: reaction may vary from pH 5.5 to 7.5:			
(1) By the 100-pound bag or 200-pound bale or box			
(2) By the ton (2,000 pounds); in 100-pound bags or 200-pound bales or boxes			
(3) By the carload: loose bulk; state approximate number of pounds or cubic yards per ton to carload			
Reed muck or sedge muck (peat humus); dark brown to black; granulated; slightly acid to slightly alkaline in reaction (pH 5.0 to 7.5); free of lumps; low in ash content (8 to 15 percent); low in content of woody material and mineral matter such as sulfur and iron; water-absorbing capacity ranging from 100 to 350 percent; water content not to exceed 50 percent by weight on oven-dried basis; moisture content in excess of 50 percent may be accepted, but settlement will be made on basis of weights corrected to 50 percent moisture content; 5-pound sample required:			
In bags of approximately 100 pounds:			
(1) By the bag (bidder to state exact number of pounds to the bag)			
(2) By the ton (2,000 pounds)			
(3) By the carload; loose bulk; state approximate number of pounds or cubic yards per ton to carload			

Advantages of Peat Materials for Soil Improvement

The addition of organic matter to soils is one of the oldest methods used to improve its physical condition, to reduce run-off and erosion, and to increase plant growth. Its greatest effect is on the structure of mineral soils. Heavy clay soils are lightened, made more granular, less plastic and consequently more permeable to water, air, roots, and micro-organisms; in light sandy soils the effect is in binding the soil particles, retarding excessive percolation, increasing the stability of the soil aggregates, and making them more retentive of moisture and nutrients. The beneficial effects were known to farmers and gardeners long before it was understood in what ways incorporation of organic matter in the form of composts or barnyard and green manures acted as soil amendments, served as food for micro-organisms, or augmented crop production.

A number of distinct types of peat have been used for the purpose of increasing the content of organic matter in the soil and improving its condition for the growth of plants. The available literature on experiments with peat as a soil amendment is extensive and cannot be reviewed here. However, many previous tests of the value of peat have failed to describe the type and quality of peat used or the character of the soil to which it was applied. Specific results are known only in a general way (*23, 26, 36*) and no careful experimental investigations have been made of the various effects under differing environmental conditions. These are some of the reasons why many State and Federal agencies have failed to indicate the necessity for the development of a program to restore organic matter in soils by means of humus-forming peat material, and why the general public lacks information regarding standards of quality and types of peat and their effect upon structural changes in soils.

Some of the experiences with peat, notably those having an alkaline reaction or containing resinous material, have been found to be unfavorable, but on the whole sufficient observations have been recorded to demonstrate that a good quality of moss peat, sedge peat, and other types of fibrous peat, as well as their decomposed phases (muck), have considerable potential value for soil improvement when properly utilized. They alter structural conditions and increase aeration and movement of water; influence the solubility of soil minerals and aid in conserving the easily soluble nutrients, as well as those contained in fertilizers applied to the soil; affect favorably the growth of roots of plants and activity of beneficial micro-organisms; increase the content of soil humus formed from the decomposition of the peat materials and improve the transfer of soluble salts from parts of the subsoil accessible to air and roots; and make the surface soil more friable and capable of absorbing more water than an untreated soil of the same kind, thus reducing run-off and erosion. The loss of soluble salts due to leaching can be reduced by adding humus-forming types of peat. The soluble nutrients are absorbed and retained for a time by the peat material, but they are returned to the soil on the decomposition of the peat; and they add nitrogen through the action of bacteria that use atmospheric nitrogen and depend on the supply of organic matter for food. Moss peat and sedge peat appear to affect also the availability of certain mineral salts and fertilizers, especially rock phosphate, and make them available for the growth of succeeding plants.

Since the addition of organic matter to soils is of great importance under most climatic conditions, the type of peat selected usually should be one that will produce the largest quantity of humus in the time desired. Owing to the uniformity and quality of the product and its advantageous physical properties, sphagnum moss peat, as well as sphagnum moss litter, is serving today a variety of purposes, especially in dairy barns, poultry houses, and for horticultural purposes. In the preparation of moss litter considerable amounts can be obtained by raking or harrowing several times during a summer the surface of deposits on which mosses grow in the form of hummocks. After exposing the mosses as a thin loose layer to wind and sun, the material is conveyed to a suitable storehouse or shed and afterwards pressed into bales.

A good quality of moss litter has properties similar to moss peat but is light grayish green or pinkish colored, undecomposed fibrous material, soft and elastic, a good absorber, deodorizer, and insulator and may be used profitably for bedding purposes and for packing fruits, vegetables, fish, meat, and eggs.

A good quality of moss peat such as that in the Juneau district, Alaska, is spongy in texture, yellowish brown in color, relatively low in pH reaction (pH 4.0–4.5), low in ash (1.5–3.0 percent on the dry-weight basis) and nitrogen, and high in water-absorbing capacity (about 1,000–2,500 percent on a dry-weight basis). It contains appreciable quantities of hemicellulose and cellulose and a relatively low content of lignin complexes. However, the organic components which tend to enrich the soil solution or develop a buffering capacity need a much more adequate characterization; hence further investigations and chemical analyses are necessary. In moss peat, decomposition is hastened by the addition of soluble nitrogen and lime; mineral nutrients in the form of complete fertilizers are also important for a gradual release of nutrients. Composts with sphagnum moss peat, owing to its disinfecting and deodorizing properties as well as its high absorptive capacity for ammonia, and the manures obtained from the use of moss peat as stable and dairy bedding and poultry litter, make this type of peat a valuable humus-forming organic material and carrier of fertilizer constituents. Several commercial preparations of manure and moss peat, such as "Driconure" and "Henure," are on the market. Other uses of moss peat include mulching for evergreen trees and shrubs to prevent injurious effects of alternate freezing and thawing, and packing of seedlings and cuttings.

Of the other types of peat, the shredded grades of fibrous sedge and reed peat are most commonly used for improving soil conditions. A good quality of humus-forming reed peat or sedge peat of the type in the Petersburg district of Alaska, is reddish brown in color, with a reaction ranging from pH 4.5–6.5, has an ash content varying between 5 and 15 percent on a dry weight basis, and a water-absorbing capacity ranging from 500 to 900 percent on a dry basis. Decomposed phases or muck are usually dark brown in color, are less acid in reaction, contain more mineral matter, and have a much lower water-absorbing capacity on a dry-weight basis. Many factors have contributed to their use: annual loss of humus in soils destroyed as the result of cultivation, run-off, and erosion; decrease in the supply of manure; increase in concentration of chemcial fertilizers; loss of soluble nutrients by leaching; structural changes in surface soils; restricted and unsymmetrical growth of roots.

The main advantages from using sedge peat and related types of peat as humus-forming material are its low ash content, freedom of weed seeds, and the ease of incorporating the peat material with a mineral soil, making it looser, more friable, more retentive of nutrient salts, and favoring a freer movement of water and roots of growing plants. It is mainly as a source of humus-forming and soil-improving material of a relatively persistent nature that sedge peat, reed peat and cultivated phases or muck have the greater value. The extent to which the improvements take place under varying soil conditions is not well known. However, there is little loss through leaching of soluble mineral salts as the peat material undergoes decomposition in the soil, and the nitrogen contained in the peat in form of resistant organic complexes becomes partially available in time. On that account sedge and reed peat are used also to a considerable extent in making composts. In many parts of the United States these types of peat could be used to good advantage for making compost heaps. The practice is an old one, especially in European countries. Some of the possibilities for composting with fish scrap, slaughterhouse wastes, sewage, lawn clippings, straw, leaves and trimmings from vegetables, garbage, and other materials are well worth consideration in order to supply the soil with organic matter and nutrients. Among the publications on this subject are those by Manns and Goheen (*25*), Snyder and Wyant (*35*), Dachnowski (*8*), Waksman (*42*), and others. Composts contain mineral constituents in a more available form and they do not cause nitrogen starvation which accompanies the decomposition of raw manure as well as raw peat by micro-organisms.

It should be borne in mind that a peat compost is not a balanced fertilizer. For this reason it is advisable to supplement it with chemical fertilizers. Decomposition of raw acid peat materials is improved by the use of available potash, phosphate, and a small quantity of lime. An excess of soluble nitrogen retards decomposition and results in loss.

The rate of application of peat materials or peat composts should be governed by the character of the soil as well as the kind of plants to be grown. Moderate applications will usually bring better results. Peat materials or composts should be well mixed with the surface soil by raking or preferably by means of a compost mixer. Thorough preparation and granulation of the soil and peat mixture is essential for the purpose of improving its physical condition and especially important in the case of humus-forming types of peat. Applications of moss or sedge peat and muck should be completely turned under in the fall or early spring to allow for partial decomposition. The peat materials decompose most rapidly when the soil is well supplied with moisture and with a liberal dressing of a nitrogenous fertilizer. Some advantage is also claimed for the furrow method of application where only a small quantity of peat or peat compost is required to increase the content of organic matter in the soil

Methods Employed in the Manufacture of Commercial Peat Products

The processes and operating methods employed for the commercial utilization of peat resources for fuel and related products have been described by Odell and Hood (*31*) and by Haanel (*20*). A brief statement of the steps taken in the development of a peat industry that would yield products for use in soil improvements was given earlier by the writer (*12*). It was also pointed out (*9*) that the suitability of a peat deposit for economic purposes depends upon (1) location, facility for drainage, and accessibility to shipping points and markets; (2) type and quality of peat material and its relative freedom from stumps and roots, colloidal organic residues and mineral matter; (3) depth and thickness of fibrous layers of peat not less than 3 to 5 feet; (4) acreage sufficent in extent to warrant operations and the establishment of a plant.

Aside from their value as a source of fuel for power production, hydrogenation, carbonization, and recovery of chemical byproducts, and as an insulating, packing, and preservative material either in the form of compact slabs or loose mull, the most successful commercial utilization of moss and sedge peat has been as organic soil amendments. The objective of the following account is to describe the essential preliminary operations and to summarize the methods and difficulties involved in the production of marketable humus-forming peat products from muskegs.

DRAINAGE

The first operation in the preparation of an area of peat selected for commercial utilization should be drainage. Good drainage is important not only for removing the excess of water contained in peat materials and reducing the weight of the material to be excavated and handled, but it is essential also for clearing the area of trees and shrubs and producing a firm working surface. A good drainage outlet and shallow open ditches used as mains and laterals or cross drains are preferable to a few deep ones, since the effects of a drain extend only for a short distance from the walls of the ditch. Where areas of peat have been overdrained, the water level can be raised and objectionable conditions can be remedied or controlled by the use of dams placed in outlet ditches. The drainage system should be adequate to remove any excess of water following a heavy rainfall without resulting in too great a lowering of the water table and unnecessarily increasing the risk of damage by fire. A peat deposit settles more or less rapidly after drainage if the layers of peat are coarsely fibrous and the ditches are deepened from year to year.

The distance between parallel lines of ditches depends on rainfall and on the type and texture of peat materials, the thickness and nature of the underlying peat layers, and the bottom relief of the mineral substratum. Peat areas with a convex or raised surface and those with a sloping surface can be drained as deep as the fibrous layers are found. Flat and valley deposits, however, which lie in water basins, can be drained only at great expense (*9*).

EXCAVATION

Several methods of excavating peat material are in use by producers in the attempt to simplify the process, increase the output, and reduce the cost of production. The more important of these methods consist of spading, harrowing, and digging by means of mechanical excavators.

In Europe much of the peat material is excavated with a specially shaped spade or slane (fig. 24), which cuts two sides of the peat block at one stroke. The blocks or sods are brick-shaped and of uniform size, lifted with forks and spread on the field to dry or carried in barrows to a drying area on higher ground adjacent to the peat deposit for overwintering. The peat is cut vertically as well as horizontally in areas in which the layers of peat are uniform, relatively thick, and show little variation or damage from uneven drying and crumbling. The sods are generally 5 by 5 by 12 inches in size. Hand cutting is resorted to where labor is cheap and plentiful. A skillful workman is able to cut in 6 hours from 3,000 to 4,000 sods. In such cases the peat area is divided into squares of suitable size. The sods are spread on the drying ground and later stacked in small loose piles for further air-drying or hauled by a small trackway to the central drying and operating plant. It is reported that three workmen can cut and spread approximately 20 tons of air-dried peat in 1 week by the use of the slane spade as a cutting tool. One ton of air-dried peat per man per day appears to be the usual estimate. From time to time various small machines to cut peat sods have been devised but they have been superseded by more complicated power-operated excavators.

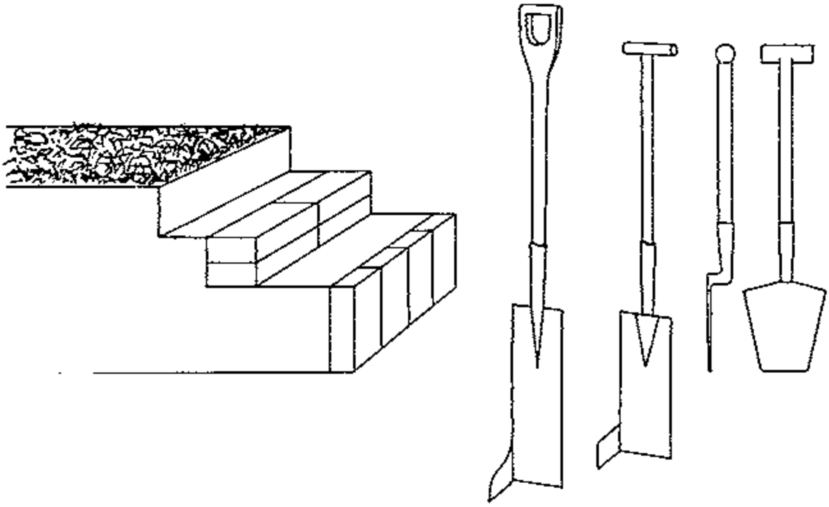

FIGURE 24.—Slanes used for hand-cutting of blocks of peat and method of excavation.

In this country the surface of some peat areas is harrowed. The process is relatively simple and consists essentially in clearing the peat area of all vegetation, harrowing the surface, or plowing and later harrowing it thoroughly in such a manner that the loose material in the top few inches evaporates much of its moisture. The type of peat and drainage conditions of the deposit should determine the kind of harrow to use. Rototillers and rotary harrows, carried on caterpillars, shred a peat layer to considerable depth, while disk harrows or spike-tooth and spring-tooth harrows give rise to clods and lumps of peat material. A thin layer about 2 inches or more thick is air-dried to a water content of 45 to 50 percent, scraped or raked several times, loaded into cars of a light narrow-gauge railway laid on the peat area at convenient distances. It is then piled or transported to drying sheds for further treatment.

Haanel (*20*) states that at the Welland, Canada, peat deposit, five men with one horse were able to gather about 3,000 cubic feet of air-dried peat daily which would yield about 23 tons of the commercial product. There are machines with caterpillar traction and a combined harrowing and elevating mechanism capable of being raised or lowered according to the depth of the harrowing to be made. The excavating portion scrapes thin slices of peat material and elevates it to a conveyor from which it is spread over the surface of the peat area to a distance of 30 to 50 feet. It forms a thin cover of coarsely shredded material which is dried by the air and sun. Successive slices several inches in thickness can be scraped or harrowed, spread, and collected according to weather conditions without affecting materially the drying process.

Various types of mechanical, automatic, and continuous excavators have been devised which need not be described or discussed here. European operators have devoted considerable attention to these. Some are of the bucket and endless chain type; but these are unsuitable for use in peat deposits where roots and stumps of trees and layers of colloidal or sedimentary peat are present to any extent. Others are designed to travel on the surface of the peat area by means of caterpillars with conveyors or spreaders which automatically dump peat material on the drying-ground. Still others represent a floating dredge with pipe-line attachment, or hydraulic excavation with suction pump for conveying the peat in the bottom of a working trench or pond to the adjacent drying field. These lines of development in Europe and data relating to the machines used for peat production may be found in the reports by Haanel (*20*), Odell and Hood (*31*), and Davis (*15*).

From a national standpoint it is obvious that areas from which peat has been excavated, as well as deposits that cannot be worked for commercial or agricultural uses should be preserved for storing water supplies and as wildlife reserves.

AIR-DRYING

The drying of peat materials on a large-scale production is a factor of economic importance which has led to the adoption of various devices for reducing the moisture content. Numerous failures have resulted from attempts to accomplish the drying of peat by artificial methods of dehydration, either by pressure in various types of machines or by heat, including partial carbonization. In all types of artificial driers, devised for evaporating the excess water from peat, the necessary pressure or heat is supplied by the combustion of fuel. The principal cause of failure of dehydration projects may, therefore, be the cost of fuel. Fruitless efforts along the line of artificial pressing and drying have convinced European and Canadian investigators of prominence that the natural air-drying process is the only practical method from which to expect a reasonable degree of success in preserving the absorptive properties of the material and in attaining a lower cost of production.

In air-drying operations, the rapidity with which evaporation of moisture in peat materials occurs depends principally upon the length of the drying season and the atmospheric conditions of which wind and temperature are the important factors. The quantity of moisture in the atmosphere under various conditions of temperature, including a discussion of the moisture content of the air in different climates and regions, are given in publications of the Weather Bureau.

The rate of drying of cut blocks or harrowed peat spread on the field is dependent on the nature of the surface of the drying field, the method of stacking or spreading the material, and on the seasonal weather conditions.

A peat deposit covered with sphagnum mosses and sedges, and properly drained, provides a favorable surface for drying blocks and sods of peat under climatic conditions of Alaska. The surface of a burned-over peat deposit, or one from which the vegetation cover has been removed, is not suitable for drying blocks of peat. Areas with low shrubby growth which can be pressed down by machinery supported on caterpillars become smooth and efficient drying fields. In very humid climate or rainy seasons a procedure essential to proper drying of peat sods consists of trestles of various forms, roofed huts, or drying sheds. A common method in northern Europe is to spear sods of peat on sharp-pointed stakes or cross-arms projecting from poles set in the peat area. Drying proceeds freely and shrinkage takes place on all sides of the peat blocks, if they are turned from time to time to expose the underside to the air, or collected and stacked in loose open piles 4 to 5 feet in height. Satisfactory results have been obtained by employing a portable belt conveyor supported on caterpillars for spreading and collecting air-dried sods, but turning of sods or blocks is generally performed by manual labor and an ordinary hand rake is the only implement required. Transportation of the blocks of peat to the central plant may require portable field tracks and small dump cars which are loaded and delivered to the main track by means of manual labor or a tractor.

For harrowed peat materials a different practice is required. The material is raked several times and subsequently scraped into piles. It remains in a piled condition for several months or else is transported by belt conveyors or cars to storage sheds and spread out in a thin layer in order to dry to a uniform moisture content. Mechanical operations have been devised, with varying success, whereby a harrowing and spreading machine on caterpillars scatters the peat material in long rows parallel to narrow-gauge tracks and in such widths and thickness as may be desirable. The advantages of this method of spreading and drying are important. The material is lightly deposited, is relatively loose, and in this way a smooth upper surface is produced which dries more or less uniformly and rapidly. A further advantage is that the thickness of the harrowed peat can be regulated according to the general drying conditions prevailing, i. e., the material is spread more thickly in the summer months and thinner during later or more rainy seasons.

SHREDDING AND GRADING

After being brought to the central plant, the air-dried, brick-shaped blocks of peat as well as furrow slices and harrowed material, including clods and coarse lumps, must be passed through a tearing machine or shredder. Shredding machines are of different sizes and construction but built on the same principle. The simpler type of shredder is more or less similar to the shredders and soil mixers used on the farm; it consists of two drums provided with teeth which rotate with different velocities against each other. Some of the more complicated types, suitable for commercial peat operations, have rotating or fixed knives, while others are swing-hammer shredders which resemble those used for shredding pulpwood. The smaller and simpler shredders are operated by hand power and those of larger capacity are driven by motor power.

From the shredder the peat material passes through a screening system. This consists mainly of rotating sieves differing in size of meshes and capacity. The coarser material is removed from the finer grade and the two products are afterward transferred to presses or to bagging machines and baled or bagged separately. To prevent the formation of combustible peat dust, it is very important not to reduce the moisture content of the material to a point below air-drying where it becomes brittle, absorbs air, resists wetting, and pulverizes to peat dust.

Uniformity in type, quality, color, and texture is of great importance in disposing of any commercial peat product. This cannot be secured without grading. Standard grades furnish the basis for imports and for trade in domestic types of peat. Uniform and well-recognized grades of moss peat, sedge peat, and its various decomposed phases (muck) are essential for market information, inspection, and sales. Standard types of peat and uniform grades eliminate friction between producers and dealers, reduce losses caused by misunderstanding and rejection, and discourage the use of inferior products.

The number of grades should be kept preferably to only two, or at most three—a fine textured and one or two coarser products. During recent years tentative standards of type and grades of peat material have been worked out by the Department of Agriculture. They are described on page 72 in terms to meet the quality requirements for interstate commerce, and they have been adopted by some of the Federal and State agencies and leading producers.

PACKING AND MARKETING

Commercial peat products are shipped to the market in bulk carloads (cubic yards or tons) and in various containers including baskets, lightweight wire-bound boxes and crates, burlap bags and paper cartons. Several of the containers provide an uncertain measure of the contents or do not stand shipping and storing for any length of time either under cover or in the open. During recent years considerable progress has been made in standardizing the size of some of the containers used. A further advantage would be the practice to indicate contents in terms of cubic feet or yards per unit weight.

The sale unit for imported moss peat is the bale. The presses used for baling are vertical, strongly constructed of wood and built either for hand power or motor power. The shredded, even-textured, spongy moss peat is pressed down to one-third or one-fourth of its original volume and while in the press the bale is covered with burlap, secured with 6 to 10 slats of wood, and bound with iron wire. The standard bale contains one-third cubic meter of spongy moss peat (about 12 cubic feet or 20 bushels, sufficient to cover an area of 250 square feet 1 inch deep); it is low in mineral matter and woody or fibrous (cottongrass) material; the moisture content ranges from 15 to 25 percent and the average weight of the bale is approximately 140 to 160 pounds.

Among domestic producers there appears to be a trend toward the use of lightweight wooden boxes, burlap bags, and special paper containers. There is still need for the elimination of many sizes and for properly identifying and describing the quality of the material by distinctive names, trade-marks, or certificates. The large variety of sizes and kinds of containers in use has increased the machinery necessary to manufacture peat products and it has added to the cost of the product to the consumer. The peat industry is growing so rapidly that facts relating to recent methods, processes, machinery employed, and the present variety in commercial peat products should receive more careful consideration.

Much of the marketing problem in commercial peat products belongs to the fields of economics. It includes transportation, distribution, costs, marketing agencies, and cooperative organizations, and it requires a knowledge of the fundamentals of economics. The essentials for success in profitable marketing of peat products are: A standard type of peat material; uniform quality of the graded product; good packing and handling methods; selection of deposits located favorably with respect to markets; and organization to ascertain important commercial facts and avoid the added cost imposed by freight rates, sales, and competition with supplies from other producers or with inferior products.

One of the great difficulties that is holding up the development of a domestic peat industry is lack of organization among the producers for the purpose of establishing and maintaining high standards of quality, ascertaining important facts upon which to base sound judgments, and developing the market for humus-forming types of peat material in order to achieve large-scale production and economy in transportation, delivery, and other costs. It is important that producers and dealers who do their own marketing devote time and study to what the market demands both in products and methods of handling the material used as soil amendment. Special attention should be given to the standardization of products and to the specifications describing the material and its properties required by Federal, State, and private agencies. The producer is responsible for the quality of the product and the improvements that can be made in producing and marketing the commodity. He can improve the grading and packing of his product, and the shipping and handling of it. These improvements would aid greatly adequate research of the benefits to be derived from the use of humus-forming types of peat, and they would not only help to dispel popular misconceptions concerning the effects of additions of peat material to the soil, but they also would stimulate the sale of the commodity to retail and wholesale dealers and other kinds of buyers. Cooperating marketing has been employed to a very limited extent. There have been some failures, probably due to lack of proper information, poor methods of operation, or indifference toward cooperation and management. Cooperative associations to be successful should be organized on a basis of producers of standard qualities of peat products and regional markets.

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