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HENRY P. HANSEN, Ph.D.

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PREFACE

This is one in a series of pollen studies of post-Pleistocene peat and other pollen-bearing sediments in the Pacific Northwest. Bogs in British Columbia, northern Idaho, many parts of Washington, and in west central Oregon have been analyzed and the forest succession interpreted from the pollen profiles. A tentative climatic trend has also been suggested. It has been shown that most of the bogs had their origin soon after the recession of the last continental ice sheet, and thus record most of the postglacial forest succession in adjacent regions. This study is the second of Oregon peat deposits, and the author expects to make many more analyses in Oregon and other parts of the Pacific Northwest. Eventually, a correlation will be made of most of the pollen profiles and a picture of post-Pleistocene forest succession and climate reconstructed for the entire region. Many of these peat deposits lie within different climax vegetation areas. This fact should aid in the interpretation of specific fluctuations and in the evaluation of the pollen profiles. The existence of the same species of forest trees in several climax regions with different climates should help to clarify the meaning of their pollen profile fluctuations rather than to confuse them.

The expenses of collecting the field data and of the materials used in preparing the peat for microscopic analysis were defrayed by a grant-in-aid from the General Research Council of the Oregon State System of Higher Education.

The author thanks Dr. I. S. Allison, Department of Geology, Oregon State College, for his suggestions concerning the geological aspects of the paper.

Department of Botany
Oregon State College

HENRY P. HANSEN

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Paleoecology of Two Peat Deposits on the Oregon Coast[1]

I. INTRODUCTION

The fact that the state of Oregon lies south of the boundary of continental Pleistocene glaciation eliminates the use of this geological event as a direct means of dating peat deposits on the Pacific Coast. Peat and other pollen-bearing sediments located within the glaciated region of North America may usually be dated as to their maximum ages by this criterion. It is difficult, however, to estimate the amount of postglacial time that had elapsed before their initiation, making it impossible to determine their minimum ages with any degree of certainty. Peat deposits that exist not too far beyond the limits of Pleistocene glaciation may often be correlated with conditions indirectly the result of glaciation, and thus shown to be post-Pleistocene. Many physiographic conditions existing in the unglaciated region owe their origin to indirect glacial action or glacial retreat, and serve as chronological criteria for peat deposits within this region. In the study of peat and other pollen-bearing sediments that lie on unglaciated sites, the existence of various conditions indirectly a result of glaciation, denote that they are of post-Pleistocene age. It seems pertinent to discuss briefly a few of these evidences for postglacial inceptions. Many bogs in the Driftless Area of Wisconsin have been developed in lakes formed in tributaries by aggradation of main stream valleys with glaciofluvial sediments. The main streams headed near the ice front. Bogs developed in oxbow lakes on the glaciofluvial sediments of the main streams and also those on postglacial fill of their tributary valleys are necessarily of postglacial age. Pollen-bearing sediments that accumulated in depressions in glaciolacustrine deposits such as those of Glacial Lake Wisconsin in the Driftless Area are also postglacial (Hansen, 1933, 1937).

Peat deposits in the Willamette Valley of Oregon, at an elevation of 400 feet or less, are postglacial, because this area was inundated by backwater from the glacial-swollen Columbia River as shown by the presence of erratic boulders on and above the valley floor (Allison, 1935). In most cases peat has accumulated in lakes formed in abandoned stream valleys that were blocked by their own former tributaries. Bogs formed in kettle-ponds in

[1] Presented before the meeting of the Ecological Society of America, June 1941, Pasadena, California.

glacial outwash south of the Vashon drift border in the Puget Lowland of Washington are of post-Pleistocene age. Peat deposits on the west side of the Olympic Peninsula a few miles from the Pacific Ocean are underlain with glacial outwash from mountain glaciation to the east, and are also necessarily postglacial (Hansen, 1941b). Lake sediments south of the drift-border in east central Washington may be dated as post-Wisconsin or possibly post Early-Wisconsin, because they have been deposited in a drainage channel that carried meltwater from one or several Wisconsin glacial stages (Hansen, 1941d). A bog formed in a landslide depression in the Wenatchee Mountains of central Washington is of uncertain age because there are no glacially derived physiographic conditions nearby (Hansen, 1939c). The presence of a volcanic ash horizon in the peat, however, is indicative of a postglacial inception. This is substantiated by the existence of the ash in other bogs lying directly upon glacial drift in the same general region. An ash layer overlies the Wisconsin drift in north central Washington, which dates it as definitely postglacial.[2] The occurrence of a single layer of ash in post-Pleistocene bogs throughout the northern half of Washington and adjoining Idaho tends to correlate all layers with the subaerial deposit on the Wisconsin drift. There is evidence that the ash in eastern and northern Washington came from Glacier Peak located in the northern part of the state, while ash in peat bogs in the Puget Sound region may also have had a similar source. Volcanic ash and pumice layers occur in postglacial peat deposits and lake sediments in the Willamette Valley and the Cascade Range of Oregon. The ash and pumice probably owe their origin to volcanic activity in the Cascades. The eruption of Mount Mazama, forming the caldera holding Crater Lake, and the eruption forming Newberry Crater occurred relatively recent in postglacial time (Williams, 1935, 1939). These two eruptions are apparently recorded by two pumice layers in a montane peat deposit about thirteen miles west of Bend, Oregon. Peat deposits farther south in the Cascade Range rest directly upon a thick mantle of pumice. The writer has been unable to ascertain whether there is an earlier sequence of peat deposits beneath the pumice. Two or more periods of volcanic activity from several scattered volcanos in the Oregon Cascades may tend to complicate a valuable criterion for the chronological correlation of pollen profiles from bogs in several different regions. On the other hand, it is believed that the presence of several layers in some instances will help to facilitate such correlations as to time and forest succession. It is perhaps possible to assign the sources of the pumice layers to the respective eruptions by means of petrographic analysis.

[2] Information from A. C. Waters, Dept. of Geology, Stanford University.

The apparent absence of volcanic ash horizons in bogs along the Oregon Coast may have been due to the prevailing west winds at the time of the eruptions. This is further suggested by the occurrence of the pumice mantle to the east and north of Crater Lake. It is realized, however, that the finer ash may have been carried in other directions by upper air currents. The bogs of this study are dated as post-Pleistocene by yet another group of physiographic conditions that were brought about by a series of geologic events indirectly a result of Pleistocene glaciation, as will be shown later.

II. CHRONOLOGY OF OREGON COAST PEAT DEPOSITS

The physiographic history of the Oregon Coast is complex and has not been thoroughly worked out. The following discussion is general, but it is believed that the more recent geologic events suggest that the peat deposits in this region are of post-Pleistocene origin. Along the southern Oregon coast are a series of well-defined marine terraces, which become less definite farther north. These terraces are covered with Pleistocene sediments and are of Pleistocene age (Diller, 1901). Conspicuous trenching by the streams flowing across the terraces indicates an uplift or eustatic lowering of sea level. Narrow valleys within broader ones suggest more than one upward movement, while final pronounced trenching occurred when the sea level was lowered by Pleistocene glaciation. During deglaciation the ocean again assumed its former level, drowning the valley mouths of streams for many miles inland. The Columbia Valley is drowned for 140 miles, the Umpqua for 25 miles, and the Coquille for 30 miles inland (Fenneman, 1931). Shorter streams rising on the west slope of the Coast Range are drowned for lesser distances inland because of their steeper gradients. Although some subsidence of the land may have occurred during the post-Pleistocene, raising of the sea level because of glacial wastage was probably sufficient to cause significant drowning of the valley mouths. The final adjustment in the relative positions of the land and ocean was followed by the marine erosion cycle of the submerged shoreline. This cycle is apparently still in an early youthful stage. Many of the embayments have been cut off by bars, and continued prograding by shore agents has further separated by wide expanses of beach the lakes thus formed. The sand is washed upon the beach and is gradually carried inland by the winds, forming extensive sand dunes parallel with the shore. Some of the lakes are more than a mile inland, with sand dunes a hundred feet or more in height isolating them from the ocean. The lakes are often drained by small streams that have been turned to flow parallel with the sea-shore for the last several miles before debouching into the ocean. Shifting sand dunes may block these streams temporarily and at intervals to form chains of fresh water lakes that support various stages of hydrarch plant succession. Further shifting of the dunes or progression of the marine erosion cycle destroys or drains these lakes with eventual destruction of the existing plant hydrosere. Other ponds or lagoons near the shore and at sea level support halophytic hydroseres, because of salt water seepage into the depressions during high tide. Farther inland the estuaries of streams also support halophytic marsh vegetation, where tidewater does not inundate the floodplain to any great extent. Many of these lakes with their hydrarch plant succession are undoubtedly ephemeral and have existed for short periods of time. Larger lakes farther inland, however, with extensive accumulations of peat probably had their origin soon after the melting of the glaciers in other parts of the continent. The foregoing sequence of events suggests that such bog formation along the Oregon Coast has been post-Pleistocene, but as in the case of other postglacial bogs in the Pacific Northwest it is not possible to estimate the period of postglacial time that elapsed before the accumulation of peat and other pollen-bearing sediments began.

III. CHARACTERISTICS OF WOAHINK LAKE BOG

Woahink Lake is one of several formed by the drowning of valley mouths a few miles south of the Siuslaw River and the town of Florence. The dendritic shoreline of these lakes with their many arms was formed by the inundation of the mouths of short tributaries to the main streams. This type of dendritic shoreline and the absence of delta deposits suggest that drowning has taken place recently, certainly not earlier than post-Pleistocene. The adjacent terrain is rugged, and with the heavy precipitation in this region the results of erosion would probably have filled most of these arms if the lakes had existed during the Pleistocene. Woahink Lake is about two miles long, one-half mile in width, and lies about two miles from the ocean. It is fed by several short streams and is drained by a single stream into Siltcoos Lake about one-half mile to the south. The latter drains directly into the Pacific Ocean two miles to the west. The Coast Range rises immediately to the east. The peat and other pollen-bearing sediments of this study have accumulated in the eastern arm of the lake. A short stream enters the inlet, increasing the rate of sedimentation by the deposition of silt and clays.

Much of the shore of Woahink Lake is steep, which has inhibited the development of a well-defined hydrosere except where sedimentation by incoming streams has made the water shallow. The bog comprises about 100 acres, most of which is in sec. 24 of T. 19 S., R. 12 W. About 35 acres is covered with *Sphagnum* moss, while the surrounding area is in the swamp stage. Cattail (*Typha latifolia*) is the chief dominant of this associes. Other plants in the swamp zone include bulrush (*Scirpus validus*), hardhack (*Spiraea douglasii*), sedge (*Carex* sp.), and a few species of willow. In the water near the shore exists a submerged hydrosere consisting chiefly of water milfoil (*Myriophyllum spicatum*), followed shoreward by a floating hydrosere of pondweed (*Potamogeton natans*) and yellow pond lily (*Nymphozanthus polysepala*). The principal plants in the Sphagnum area include Labrador tea (*Ledum columbianum*), evergreen huckleberry (*Vaccinium ovatum*), cranberry (*V. oxycoccus intermedium*), salal (*Gaultheria shallon*), sundew (*Drosera rotundifolia*), purple marshlocks (*Potentilla palustris*), pitcher plant (*Chrysamphora californica*), cottongrass (*Eriophorum chammisonis*), hardhack, willow, and sedge. Trees in order of their invasion are lodgepole, or shore pine, (*Pinus contorta*), Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and red alder (*Alnus rubra*). The trees have as yet made only a limited invasion of the bog, and most specimens are stunted, indicating that hydrarch succession has not reached a stage favorable for rapid forest invasion. Lodgepole pine is often the first and most abundant invader of peat bogs in the Pacific Northwest (Rigg, 1940).

Peat samples were obtained at quarter-meter intervals with a Hiller peat sampler. Several test holes were bored and the deepest point located was 11.75 meters. At this level the sediments consist of a yellow-stained sand mixed with silt, which is present to 11.25 meters. Gray clay exists from 11.25 meters to 8.25. A shallow layer of brown sedimentary peat is present from 8.25 to 7.5 meters, followed by another layer of clay to 6.75 meters. Brown sedimentary peat extends to 5.25 meters, from which point brown fibrous peat is present to the surface. The Sphagnum apparently exists as a floating mat for a distance of 100 feet from the shore. Wood is present at 11.25 meters, suggesting the existence of a forest when the valley mouth of the original stream was inundated. Charred wood occurs mixed with the clay at 9 meters. A detailed profile of this bog shows several extensive layers of wood peat (Rigg and Richardson, 1938).

IV. CHARACTERISTICS OF SAND LAKE BOG

Sand Lake is located about 100 miles north of Woahink Lake and has apparently had a similar origin. The town of Tillamook is situated about eleven miles to the north. Sand Lake was formed by the drowning of Sand River Valley mouth and valley mouths of several other streams that empty into the ocean near the same point. The lake is about one mile from the ocean and is drained into it by a single stream, flowing southwest. The lake and subsequently deposited sediments have evidently had a postglacial inception, resulting from a sequence of geologic events similar to the sequence that occurred in the vicinity of Woahink Lake. Sand Lake, however, was ponded in a much broader valley, it being more than two miles wide the last several miles of its course. The sediments overlying the valley floor are largely lacustrine, and much of the surface has been cleared and drained for cultivation. The streams in this region show less entrenchment than those farther south, suggesting a smaller degree of uplift during the Pleistocene and later. The relative importance of uplift, trenching, and filling is not as clear as in the Woahink Lake region. Less uplift is further suggested by the fact that the sediments are more shallow than in the latter, indicating less downcutting, which in turn marks a smaller difference between sea level and the original valley floor. The prehistoric area of Sand Lake bog was many times greater than that of the other bog, and it was in a climax vegetation stage before it was cleared. Relict areas of Sphagnum persist at several points farther up the valley, however, in pockets too deep for draining. There is no topographic map of this region and it is difficult to interpret the physiography by means of a cursory survey. Peat samples were obtained in a virgin area of Sphagnum comprising about 100 acres, three-quarters of a mile up the valley from Sand Lake, in sec. 20 of T. 3 S., R. 10 W.

The Sphagnum area supports an ericad associes of Labrador tea, huckleberry, and cranberry. Other plants in this zone include sundew, cottongrass, wild lily-of-the-valley (*Mianthemum dilatatum*), wintergreen (*Pyrola chlorantha*), twinflower (*Linnaea borealis longiflora*), and hairycap moss (*Polytrichum juniperinum*). A shallow, natural stream flows intermittently through this part of the bog, and it and other areas of standing water support such plants as yellow pond lily, cattail, purple marshlocks, skunk cabbage (*Lysichitum americanum*), buckbean (*Menyanthes trifoliata*), *Limnorchis leucostachys, Cyperus erythrorhizos,* and *Carex* sp. Near the outer edge of the bog in more mesophytic areas grow salal, wax myrtle (*Myrica californica*), red alder, hardhack, deer fern (*Struthiopteris spicant*), bracken fern (*Pteridium aquilinum pubescens*), *Epilobium* sp., western dogwood (*Cornus occidentalis*), and two species of willow (*Salix* spp.). This area is being rapidly invaded by trees. In order of their invasion are lodgepole pine, western hemlock, western red cedar (*Thuja plicata*), Sitka spruce, and cascara (*Rhamnus purshiana*). Trees are far more abundant than on the other bog, and in a few years the existing Sphagnum area will be indistinguishable from the adjacent forest except by its composition. Samples were obtained at decimeter intervals with a Hiller peat sampler. In the area of sampling the greatest depth is 4 meters, at which level dark sand is present. This abruptly grades at 3.8 meters into sedimentary peat, which is present to 3 meters. Dark brown fibrous peat exists from 3 meters to the surface. Charred peat is present at 2.2 meters. The absence of silts and clays such as constitute a high percentage of the Woahink Lake profile indicate that the area sampled was too far removed from the source of incoming streams for such sedimentation to occur; or that erosion was less in adjacent areas. The surrounding terrain is not as rugged as that in the vicinity of Woahink Lake, where the slopes come to the edge of the bog. The Sand Lake bog has been described by Dachnowski-Stokes (1936).

V. METHODS AND TECHNIC

In the preparation of slides for microscopic analysis, about 5 cc. of peat or silts were boiled gently for 15 minutes in a weak solution of potassium hydrate with 3 drops of gentian violet stain. The solution was then washed with twice its volume of water through cheesecloth. When tap water is used it is examined periodically for pollen grains that might have found their way into the water system if the open reservoir type is used. The solution was then centrifuged and about 1 cc. of the residue mixed with 5 cc. of warm glycerine jelly, and a small portion mounted under a 7/8-inch-square cover glass. New methods for the preparation of peat and other pollen-bearing sediments in pollen analysis have been worked out from time to time. These methods have been devised in order to overcome certain difficulties involved in deflocculation peculiar to types of sediments that do not respond favorably to the hydroxide method. Some have been devised to remove an excess of inorganic materials such as silts, which make pollen identification difficult. Other treatments are useful in concentrating pollen in peats that are low in pollen content. Fibrous and sedimentary peats in the Pacific Northwest contain an abundance of pollen, and the hydroxide treatment, if used with care, seems to be satisfactory. Too strong a concentration of hydroxide solution and long and vigorous boiling tend to cause fragmentation of pollen grains. Silts, clays, and sands may also contain an abundance of pollen, but often certain levels have a low pollen content and the hydroxide method should be replaced by one of the more suitable newer methods. Lake sediments and interglacial sediments have also shown a dearth of pollen (Hansen, 1938b, 1940c, 1941d).

One-hundred and fifty pollen grains were identified from each level with the exception of the 8.5 and 8.75 meter levels in the Woahink Lake bog. At these levels no pollen was present in the silty-clay, which perhaps was deposited by floods in a single season. The indicator species that are recorded by their pollen to less than 1.5 per cent are listed in the tables as 1 per cent (Tables 1 and 2). The pollen of nonsignificant species is also listed in the tables but it was not computed in the percentages. While this pollen may have little value for indicating the adjacent forest succession, it is often useful in recording the development of the bog itself or in substantiating interpretations of the pollen profiles of the significant species. It is believed that the great abundance of red alder pollen at certain levels lends support to the theory that fire has been responsible for the disruption of normal forest succession in the hemlock-cedar climax in the Pacific Northwest (Hansen, 1941c). The method employed in the separation of species of Pacific Northwest conifer pollen has been described in several previous papers (Hansen, 1940b, 1941a, 1941b). Peat deposits located in certain parts of Oregon will offer greater problems in pollen identification than those in Washington, British Columbia, and Idaho because of the larger number of conifer species existing here. Size ranges have been determined of specific modern pollen, taken from the tree when mature and being shed. It is realized that ecologic factors may influence the size of pollen from the same species in different areas, adding another source of error to pollen statistics. Identification is made by measuring the cell and assigning it to that species within the size range of which it falls. If the dimensions fall within the limits of overlap of larger or smaller species the pollen grain is designated as an unknown. Broken, distorted, and unmeasurable pollen is likewise discarded and listed with the former under its generic name (Tables 1 and 2). Some workers have shown that it is impossible to separate the species of *Pinus, Abies,* and *Picea* by their size ranges in certain regions. Cain (1940) has shown that the size-ranges of certain eastern species of *Pinus* may serve as a criterion in separating fossil pollen by comparison of their size-frequency curves. The writer believes that he can separate with significant certainty the fossil pollen of lodgepole pine, western white pine (*Pinus monticola*), and western yellow pine (*P. ponderosa*) by the size-range method. White bark pine (*P. albicaulis*), limber pine (*P. flexilis*), knobcone pine (*P. attenuata*), and sugar pine (*P. lambertiana*) apparently cannot be identified with any degree of certainty. The first three are within the size-range of western white pine and yellow pine, while sugar pine is chiefly within the range of yellow pine although its average size is slightly greater. It should be noted that the last three species of pine are apparently not present in Washington and thus did not play any part in postglacial forest succession in that region. Among the firs, the size-range of silver fir (*Abies amabilis*) falls within that of the smaller lowland white fir (*A. grandis*) and the larger noble fir (*A. nobilis*) and thus cannot be identified. White fir (*A. concolor*) pollen ranges much the same in size as noble fir, although perhaps with a slightly larger average. The pollen grains of red fir (*A. magnifica*), weeping spruce (*Picea breweriana*), foxtail pine (*Pinus balfouriana*), and Jeffrey pine (*P. jeffreyi*) have not been observed. These species have limited geographic ranges in Oregon, however, and are not important in the forest complex. It is impossible, of course, to estimate their prehistoric importance or successional trends under past environments. It seems unlikely that any bog analyzed to date lies within range of pollen dispersal of the last four species.

The interpretation of postglacial forest succession and climate from pollen profiles perhaps becomes more general and less significant when there are high proportions of pine and fir pollen with the possibility of several species of each genus being represented. It is probable, however, that the pines most abundant and widespread in the Pacific Northwest today have also been predominant during most or all of post-Pleistocene time. The location of peat deposits with respect to existing vegetational climax formations with their several associations, faciations, and consociations is important in the interpretation of the paleoecological history from the pollen profiles. Lodgepole, western white, and western yellow pine are the most abundant and widespread in the Pacific Northwest at present, and it seems reasonable to assume that they also were the most important during post-Pleistocene time. Jeffrey, sugar, foxtail, and knobcone pine are confined chiefly to southern Oregon and there is no evidence that the climate was more favorable for their existence farther north during any part of the postglacial period. Lodgepole, western white, and western yellow pine have been dominant east of the Cascade Mountain Range in the drier climate (Hansen, 1939a, 1939b, 1939c, 1940b). Douglas fir (*Pseudotsuga taxifolia*), western hemlock, lowland white fir, and Sitka spruce have been the principal species in the more humid climate of the Puget Lowland, Olympic Peninsula, and Oregon Coast range (Hansen, 1938a, 1940a, 1941a, 1941b, 1941c). There is no difficulty in the separation of Sitka spruce from Engelmann spruce (*Picea engelmanni*). The first is a fog-belt species confined largely to the Pacific Coast, whereas the latter is a montane species on the east slope of the Cascades and in the Rocky Mountain region. Douglas fir pollen is distinct and there is no danger of confusing it with any other. The pollen of western hemlock is also distinct, and it can readily be distinguished from that of mountain hemlock (*Tsuga mertensiana*) by the presence of bladders on the latter. There is

Table 1. PERCENTAGES OF FOSSIL POLLEN, WOAHINK LAKE BOG.

Depth in meters	11.75	11.5	11.25	11.0	10.75	10.5	10.25	10.0	9.75	9.5	9.25	9.0*	8.25	8.0	7.75	7.5	7.25	7.0	6.75	6.5	6.25	6.0	5.75
Pinus contorta	1	4	2	6	2	5	2	5	4	6	3	1	2	7	8	4	3	....	1	10	8	16	14
Pseudotsuga taxifolia	6	4	5	8	3	6	6	5	5	3	4	1	17	13	8	10	4	4	5	13	8	14	20
Tsuga heterophylla	16	14	20	32	35	41	48	50	50	38	50	50	31	33	32	46	50	53	40	18	20	25	18
Picea sitchensis	76	78	73	54	60	48	44	40	41	53	43	48	50	47	52	40	43	43	54	59	64	45	48
Abies grandis	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pinus spp.†	1	1	....	2	1	2	1	1	2	1	....	1	2	3	2	....	1	....	1	7	....	12	7
Compositae‡	....	1	....	....	....	1	....	1	....	2	....	1	1	....	3	....	....	....	....	....	....	2	....
Alnus‡	63	82	31	3	1	17	22	27	26	77	62	53	27	8	21	16	22	21	25	7	18	21	35
Myrica-Betula‡	....	1	3	....	1	2	3	2	....	....	....	1	1	....	....	....	....	3	....	....	6	....	2
Acer‡	1	3	1	2	....	1	1	....	1	3	2	7	3	1	2	1	....	4	2	3	....	1	....
Salix‡	3	1	5	1	2	....	6	3	1	2	1	2	7	....	3	....	2	3	1	1	....	....	....
Ericaceae‡	....	....	....	1	....	....	2	1	....	[illegible]	2	1	2	1	....	3	2	1	6	3	1	....	....
Cyperaceae‡	2	2	7	13	7	8	11	17	19	22	27	33	38	41	32	52	22	13	16	27	51	31	15
Typha latifolia‡	....	....	....	....	1	2	1	1	....	[illegible]	1	....	1	2	....	3	1	1	3	5	1	1	....
Nymphozanthus polysepala‡	....	....	....	....	....	....	....	....	....	[illegible]	....	....	....	....	....	....	....	....	....	....	2	....	2

Depth in meters	5.5	5.25	5.0	4.75	4.5	4.25	4.0	3.75	3.5	3.25	3.0	2.75	2.5	2.25	2.0	1.75	1.5	1.25	1.0	0.75	0.5	0.25	0.0
Pinus contorta	10	8	14	16	10	8	14	12	8	8	5	8	8	6	5	6	6	5	9	5	15	21	16
Pseudotsuga taxifolia	24	20	20	20	12	4	5	7	9	6	9	16	12	16	10	10	10	8	16	14	12	10	7
Tsuga heterophylla	17	26	30	26	38	38	40	33	41	50	46	38	36	28	28	28	25	30	19	28	33	20	26
Picea sitchensis	48	46	36	38	40	50	41	48	42	35	40	38	44	50	57	56	58	57	56	53	40	49	51
Abies grandis	1	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	....	....
Pinus spp.†	2	5	11	7	3	6	11	3	2	1	2	1	3	....	2	2	1	1	3	1	7	3	4
Compositae‡	....	....	1	6	1	2	....	1	....	2	1	....	....	2	....	1	....	3	....	1	....	....	2
Alnus‡	42	31	33	21	2	13	3	6	10	3	13	20	26	4	9	13	8	9	5	4	8	9	3
Myrica-Betula‡	....	6	....	3	....	1	....	2	....	....	....	3	1	....	....	6	....	....	7	12	14	17	19
Acer‡	....	2	6	1	....	1	1	....	3	....	7	3	....	1	....	2	....	....	2	1	....	1	3
Salix‡	....	3	1	....	....	3	....	....	1	....	....	2	....	1	....	....	1	....	....	....	2	....	1
Ericaceae‡	....	7	2	....	3	1	....	....	3	....	3	....	2	2	2	1	....	....	1	3	3	1	22
Cyperaceae‡	23	11	27	15	21	12	7	17	19	43	27	36	2	5	1	6	3	4	3	4	3	10	7
Typha latifolia‡	3	2	....	1	1	1	....	....	....	....	5	....	....	....	....	....	1	....	....	....	1	....	....
Nymphozanthus polysepala‡	1	1	1	14	....	3	13	15	....	5	....	22	....	....	....	....	7	1	....	2	....	....	....

* Charred peat.
† Number of *Pinus* pollen grains discarded, not computed in the percentages.
‡ Number of pollen grains, not computed in the percentages.

Table 2. PERCENTAGES OF FOSSIL POLLEN, SAND LAKE BOG.

Depth in meters	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2	0.0
Pinus contorta	5	3	3	6	8	8	10	10	10	3	10	15	8	14	20	18	11	13	8	19	51
P. monticola	1	....	....	....	....	....	....	....	1	....	....	2	2	2	....	6	6	3	4	8	6
Pseudotsuga taxifolia	3	1	....	2	2	1	3	3	4	3	4	8	8	7	6	10	8	7	6	7	4
Tsuga heterophylla	60	58	52	52	49	50	40	45	44	46	42	40	42	47	40	32	33	40	47	50	17
T. mertensiana	1	....	....	....	....	....	....	1	....	....	1	1	....	....	....	....	....	....	....	....	....
Picea sitchensis	29	37	45	40	40	41	46	40	41	48	43	33	40	30	33	32	42	35	35	16	21
Abies grandis	....	....	....	....	....	....	1	1	....	....	....	1	....	....	1	....	....	....	....	....	....
A. nobilis	1	1	....	....	1	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....
Thuja plicata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	1
Pinus spp.*	2	1	....	....	....	....	....	1	3	2	1	1	1	1	....	....	3	5	7	6	....
Gramineae†	2	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1	1	....
Compositae†	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Alnus†	51	7	19	5	4	7	4	7	11	2	1	5	3	5	8	8	14	5	3	9	10
Acer†	1	....	....	....	....	2	....	....	....	....	....	....	....	....	1	....	....	....	1	1	....
Myrica-Betula†	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	4	....	....	....
Salix†	1	....	....	....	....	....	....	....	....	....	....	....	....	2	1	4	....	7	....	3	1
Ericaceae†	....	2	....	....	1	2	3	....	....	3	1	4	1	....	2	5	4	3	6	....	1
Cyperaceae†	6	39	18	65	40	80	22	37	32	18	11	3	2	....	7	11	10	7	2	1	1
Typha latifolia†	2	3	....	....	2	1	6	6	12	2	2	2	....	3	61	15	12	1	8	1	1
Nymphozanthus polysepala†	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	2	....	8	....	....	....
Potamogeton†	1	1	5	....	2	1	1	....	3	....	....	....	....	....	1	....	3	....	1	....	....

* Number of *Pinus* pollen grains discarded, not computed in the percentages.
† Number of pollen grains, not computed in the percentages.

slight or little difference in the pollen of western red cedar, incense cedar (*Libocedrus decurrens*), Port Orford cedar (*Chamaecyparis lawsoniana*), Alaska cedar (*C. nootkatensis*), western yew (*Taxus brevifolia*), and western juniper (*Juniperus occidentalis*). Little pollen of these species has been present in peat profiles thus far studied, a fact which suggests that they shed small quantities of pollen, that their pollen is not well preserved in peat, or that they were not abundant within range of pollen dispersal to the bogs analyzed. In some cases all three as well as other conditions may have prevailed. In climax bogs with an abundance of western red cedar on their surfaces, only a small amount of pollen from this or other species with similar pollen has been observed in the upper levels.

Enormous quantities of alder pollen occur at many horizons in Pacific Northwest peat profiles. In pollen-bearing sediments west of the Cascade Range most of this pollen is undoubtedly from red alder, which is abundant in floodplain associes or as a pioneer invader on damp sites where the coniferous forest has been destroyed. East of the Cascades alder pollen may constitute a mixture from several species including red alder, Sitka alder (*Alnus sinuata*), mountain alder (*A. tenuifolia*), and white alder (*A. rhombifolia*). The number of alder pollen grains is not used in computing the percentages, because of the local occurrence of alder on or near the bog, and because of its doubtful indicator significance. In some profiles the fluctuation in the quantity of red alder pollen is correlated with that of Douglas fir, suggesting that it has invaded areas denuded by fire with the latter species. Pollen of sedge, cattail, water lily, pondweed, myrtle, and ericads record the progress of hydrarch succession. Fern spores are abundant at some levels in peat profiles west of the Cascades and may be from ferns on the bog or in adjacent areas. Bracken fern becomes abundant where fire has occurred at frequent intervals and has destroyed the second growth timber. No significant correlation with other species has yet been observed.

In this study the proportions of pine pollen are the lowest of any bog heretofore analyzed, indicating that all species of pine have had little importance in postglacial forest succession along the Oregon Coast. The number of pine pollen grains discarded varies from none to 12 in both profiles with an average of less than 3. The amount of discarded pollen of a genus is usually in direct proportion to the total number. In some profiles as much as 18 per cent of the total significant pollen has been discarded. It is believed that the separation by size-range of fossil Pinus and Abies pollen in the Pacific Northwest involves no more error than is inherent in the problem of pollen statistics.

VI. VEGETATION IN ADJACENT AREAS

Both bogs lie within the Humid Transition life zone (Bailey, 1936). A narrow zone, several miles in width along the coast, is often designated as the coastal strip or fog belt because of the heavy precipitation. The chief dominants of the coastal forest are lodgepole pine, Sitka spruce, and western hemlock. Lodgepole pine is most abundant near the ocean shore and does not extend inland for any great distance. It invades sand dune areas, where the edaphic conditions have been somewhat modified by the growth of herbaceous vegetation and shrubs. Spruce is also prevalent near the ocean but is not as common as pine. Trees nearest the ocean become distorted in form due to the prevailing winds and sand-shear, resembling somewhat the Krummholz form characteristic of timberline. Spruce increases in abundance and lodgepole pine thins out farther inland as the influence of the ocean becomes lessened. Hemlock may occur near the shore in more protected areas, but this species apparently is unable to withstand the adverse conditions as well as do spruce and pine. Farther inland spruce and hemlock become equal in abundance but the latter gradually assumes the majority. Hemlock in turn gives way to Douglas fir as the elevation of the Coast Range to the east increases and the precipitation decreases. Other dominants in the coastal forest are western red cedar and lowland white fir. Port Orford cedar becomes a part of the forest complex farther south, while Sitka spruce gradually thins out as the precipitation lessens.

The coastal strip and Coast Range of Oregon are within the hemlock-cedar association of the Coast Forest, according to Clements' classification of the major vegetation climaxes of North America (Weaver and Clements, 1938). In western Oregon red cedar is of minor importance and hemlock is also unimportant except along the immediate coast. Douglas fir is a subclimax species over much of the region forested with the hemlock-cedar climax. It has been able to persist as one of the chief dominants because of periodic fires that have interrupted the forest succession toward the climax. Pollen analysis of a bog in the east foothills of the Coast Range in west central Oregon shows that hemlock has never been as abundant as Douglas fir during post-Pleistocene time (Hansen, 1941c). Munger (1940) believes that the absence of hemlock as the chief dominant in west central Oregon is due to a drier climate than that existing where it is the chief dominant. This in part may be true, but the pollen profiles suggest that Douglas fir has remained as the chief dominant because of periodic fires as is the case in most of the hemlock-cedar climax region. Forests on the west side of the Olympic Peninsula are composed largely of spruce and hemlock; they have been and lodgepole pine only 1 per cent (Figure 1). The bottom of Sand Lake bog records 29, 60, 3, and 5 per cent for spruce, hemlock, Douglas fir, and lodgepole pine respectively (Figure 2). The relative proportions of spruce and hemlock are thus reversed in the two bogs, but these two species were by far predominant. It should be noted that it is not assumed that the lower strata of the two bogs were concurrently deposited. These are the first bogs analyzed in which Sitka spruce and western hemlock are recorded as the chief dominants at the bottom as well as throughout the peat profile. In a bog located ten miles from the Pacific Ocean on the west side of the Olympic Peninsula, also in a spruce-hemlock climax, lodgepole pine and western and mountain hemlock were the principal species recorded in the lowest level, while spruce recorded only 6 per cent (Hansen, 1941b). This indicates that Sitka spruce does not thrive or can not compete with other species away from the immediate coast.

In the Woahink Lake bog the percentage of spruce pollen sharply declines from 76 at the bottom to 40 at 10 meters, while that of hemlock increases from 16 to 50 per cent at the same levels respectively. They maintain more or less equal proportions to 9 meters. The presence of charred wood at the latter horizon is significant in that the two levels above are entirely devoid of pollen. The stage of hydrarch succession at this time was evidently such as to prevent fire on the bog itself as is suggested by the existence of clay at these levels. This may denote the occurrence of forest fires in adjacent areas and the deposition of charred wood by incoming streams. The absence of pollen at 8.75 and 8.5 meters marks either the destruction of the forest to the extent that no pollen was available, or the denudation of the terrain, which caused erosion to result in the deposition of several feet of sediments in a single season. Fire most likely occurred in late summer during the dry season, long after the pollen was shed. Erosion during the following autumn and winter might conceivably have resulted in the deposition of several feet of inorganic sediments containing little or no pollen. The rapid growth of vegetation the following spring and summer evidently soon reduced erosion as is suggested by the presence of brown sedimentary peat at 8.25 meters and brown fibrous peat at 8 meters. The resumption of the pollen record at 8.25 meters records 50 per cent for spruce and 31 per cent for hemlock, the latter having decreased during the interim represented by the lower two levels. Spruce pollen declines to 40 per cent at 7.5 meters and then increases to 64 per cent at 6.25 meters. It again decreases to 45 per cent at 6 meters and then fluctuates between 35 and 50 per cent to 2.25 meters. At 2 meters it records 57 per cent and then decreases to 51 per cent at the surface. Hemlock pollen increases from 31 per cent at 8.25 meters to 53 per cent at 7 meters, and then declines to 18 per cent at 6.5 meters. It again shows a gradual increment to 50 per cent at 3.25 meters from which point it again gradually diminishes to 26 per cent at the top. The average percentage of hemlock for the entire profile is 35.5 and that of spruce is 49.5. Upon this basis spruce has been generally more abundant throughout the period of time represented by the peat profile.

The pollen profiles of Douglas fir and lodgepole pine show that these species were not as important as spruce and hemlock. This is especially true for lodgepole pine, as it is an early and prolific pollen producer, and its existence between the ocean and the bog would permit the westerly winds to carry its pollen to the bog. On the other hand, Douglas fir may be somewhat under represented because of its existence leeward to the bog. Both species fluctuate between 1 and 8 per cent from the bottom to 9 meters. Douglas fir increases from 1 per cent at 9 meters to 17 per cent at 8.25 meters, which constitutes the interval of sediments devoid of pollen. If the absence of pollen is the result of denudation by fire, the decrease of hemlock pollen and increase of Douglas fir pollen during this interim may indicate the invasion by the latter on adjacent burned areas, such as usually occurs after fire in the region of the hemlock-cedar climax. The fact that lodgepole pine records only 2 per cent at the 8.25 meter level further substantiates this theory, in that the Douglas fir increment was not merely relative (Figure 1). The maximum proportion attained by Douglas fir is at 5.5 meters, where it is recorded by its pollen to 24 per cent. The minimum percentage of hemlock also occurs at this level, which is suggestive of another fire or other agencies altering the forest composition. Douglas fir maintains frequencies of 20 per cent for the next three levels and then fluctuates between 4 and 16 per cent to the surface. Lodgepole pine records its greatest abundance from 6.5 to 4.5 meters concurrently with that of Douglas fir. Its higher proportions in the upper three horizons may reflect its invasion of the bog surface in relatively recent time. It is realized that the relative proportion of pollen recorded in peat deposits by adjacent forest trees is influenced by a large number of intangible factors. One of the chief problems in the interpretation of forest succession from pollen profiles is the degree of correlation existing between the pollen percentage of a species and its relative abundance in the area from which the pollen is received. Broadleaf species in order of the abundance of their pollen are red alder, maple, and willow. Pollen listed as that of Betula-Myrica in the table is probably from *Myrica californica,* which thrives in the coastal area. The pollen of sedge, cattail, water lily, and ericads record the progress of hydrarch succession in lake and bog (Table 1).

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In the Sand Lake bog hemlock gradually decreases from 60 per cent at the lowest level to 40 per cent at 2.8 meters, while spruce slightly increases from 29 to 46 per cent at the same levels respectively (Figure 2). Hemlock fluctuates between 40 and 47 per cent from 2.8 to 1.2 meters, decreases to 32 per cent at 0.6 meter, and then increases to 50 per cent at 0.2 meter. It makes a final decline to only 17 per cent at the surface. Spruce fluctuates between

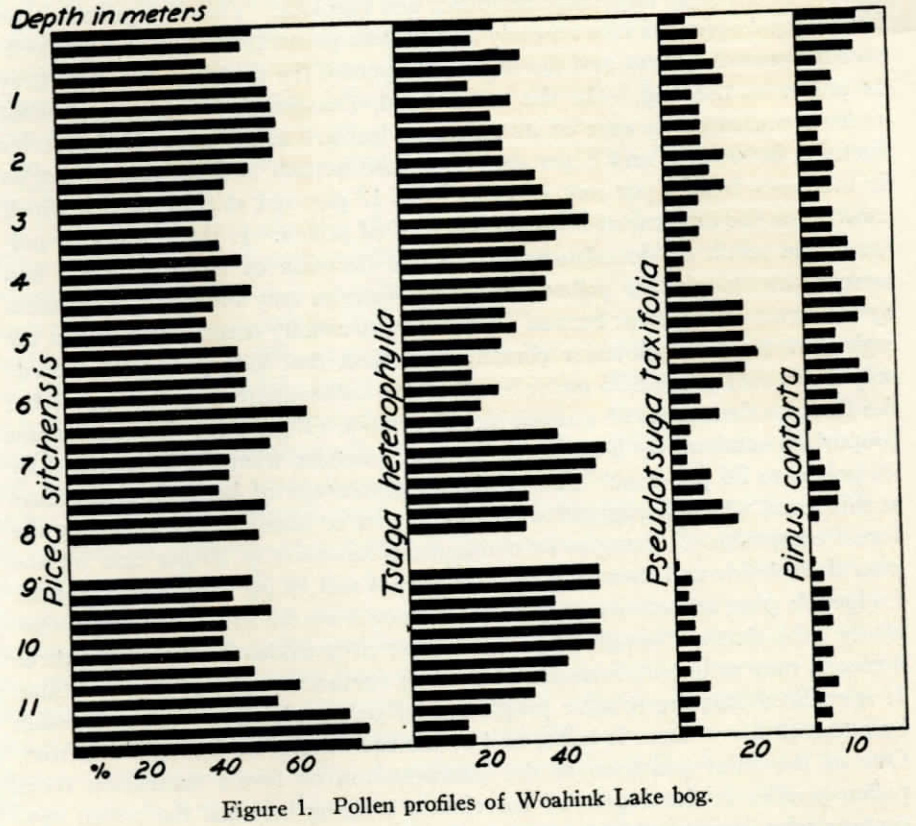

Figure 1. Pollen profiles of Woahink Lake bog.

30 and 48 per cent from 2.8 to 0.4 meter, and then diminishes to 21 per cent at the surface (Figure 2). The profiles of spruce and hemlock show less fluctuation than in Woahink Lake bog, and also show less deviation from one another. The average of spruce for the entire profile is 36.5 per cent, while for hemlock it is 44 per cent. The pollen profiles of Douglas fir and lodgepole pine show that these species were not an important part of the forest

composition during the time represented by the peat deposit. The highest percentage attained by Douglas fir is 10 per cent at 1 meter, while no pollen was recorded for this species at 3.6 meters. Pine, however, shows higher percentages throughout, with a general increase upward in the profile

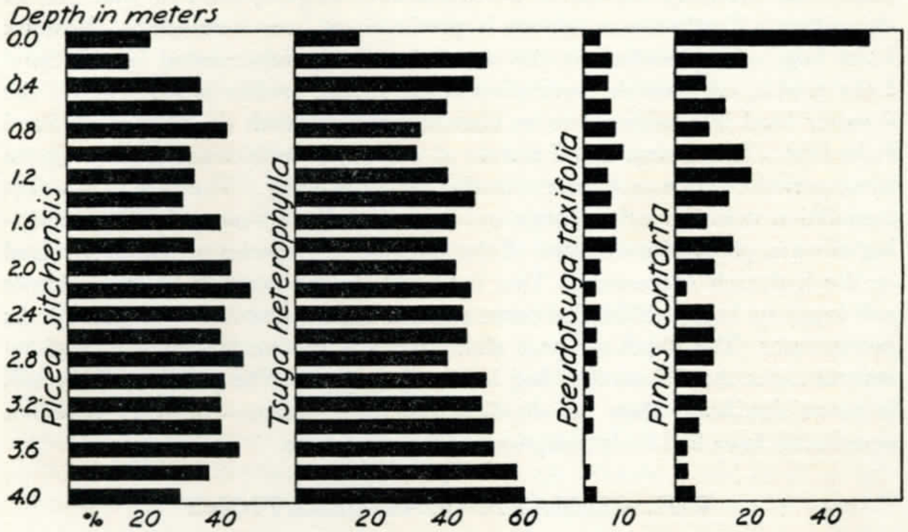

Figure 2. Pollen profiles of Sand Lake bog.

(Figure 2). Its pollen record fluctuates between 3 per cent at several levels and 51 per cent at the surface. The maximum proportion at the surface is undoubtedly a result of historic deforestation by lumbering and fire in adjacent areas as well as a recent invasion by pine of the bog itself. The general increment from bottom to top may reflect its invasion of primary areas formed by prograding of the beach by shore agents. Western white pine is sporadically recorded in the lower two-thirds of the profile, but increases in abundance in the upper levels. Its maximum proportion of 8 per cent occurs at 0.2 meter, indicating that this species has not been important in post-Pleistocene forest succession. In the bog on the east slope of the Coast Range in west central Oregon white pine pollen is most abundant in the lower horizons (Hansen, 1941c). Pollen profiles of bogs in the Puget Lowland of Washington show that white pine was generally most abundant in the lower levels, indicating that it was a pioneer postglacial invader with lodgepole pine (Hansen, 1938a, 1940a, 1941a). Other conifers sparsely recorded by their pollen in the Sand Lake bog are mountain hemlock, lowland white fir, noble fir, and western red cedar. The latter pollen may be that of western yew. Red alder is the best represented of the broadleaf species (Table 2).

The pollen profiles of the two bogs offer little evidence for chronological correlation. The Woahink Lake bog is about three times the depth of the other, and probably represents a considerably longer period of time for its deposition. Furthermore, spruce is predominant over hemlock in Woahink Lake bog, while hemlock is the most abundantly represented in the Sand Lake profile. A possible correlation of the spruce profiles is suggested if the 7 meter level is considered to be contemporaneous with the bottom of Sand Lake bog. This means that 7 meters of sediments were deposited during the same period of time as 4 meters in the Sand Lake bog. The rate of peat accumulation varies greatly in bogs and it is controlled by many factors, including climate, physical conditions of the lake, and the species of plants involved in the hydrarch succession. This is shown by the position of the volcanic ash layer in bogs within the same general region elsewhere in the Pacific Northwest. The depth of peat above the ash in one bog may exceed by several times that of another bog in the same area. The position of the ash is more significant than the depth of the bog, because the bogs may not necessarily have had their inceptions at the same time.

VIII. CLIMATIC CONSIDERATIONS

Pollen analysis of Pacific Northwest peat bogs and other sediments indicate a more definite post-Pleistocene climatic trend in areas to the east rather than to the west of the Cascade Mountain range. Pollen profiles of bogs in northern, central, and eastern Washington and northern Idaho suggest a warming and drying of the initial postglacial climate, which was followed by cooling and perhaps a slight increase in moisture in more recent time (Hansen, 1939a, 1939b, 1939c, 1940b, 1941d). Historic and recent fluctuations indicated by the drying of lakes and ring growth in forest trees are not reflected in pollen studies. This is not to be expected, however, because peat samples at quarter-meter intervals may be separated by many centuries of time. The degree of these interpreted climatic fluctuations varies somewhat for each bog, because they are located within different life zones and climatic provinces. In the Puget Lowland of Washington, on the Olympic Peninsula, and in the Coast Range of Oregon climatic trends are less definite (Hansen, 1938a, 1940a, 1941a, 1941b, 1941c.). The postglacial forest succession in these regions was probably influenced chiefly by the competition of the many species and the occurrence of periodic fires. This is especially true in the hemlock-cedar association of the Puget Lowland, where the pioneer lodgepole pine was rapidly replaced by Douglas fir, which in turn was more gradually succeeded by western hemlock. This succession was apparently largely a result of the relative tolerance of the three species for shade. In the Coast Range of west central Oregon, Douglas fir was apparently able to maintain predominance over hemlock, due to periodic fire and possibly a slightly drier climate. This is further evidenced by the occurrence of charred peat at several horizons and significant correlated fluctuations in the amounts of both Douglas fir and red alder pollen. A wide range of climate exists in the Pacific Northwest because of the proximity of the ocean, physiographic barriers, and great relief; and the climatic trends have likewise been different. Thus, it is possible that a climatic trend in one region was one of drying, while in another region it was one of increased moisture. This is suggested by a comparison of pollen profiles in the Puget Lowland and west central Oregon (Hansen, 1941c).

Tolerance of shade, moisture requirements, age of initial seed production, amount and frequency of seed production, longevity, resistance to fire, and recovery after fire seem to be the chief characteristics of forest trees that influence succession. A species does not readily respond to a fluctuating factor of the environment if it is above the optimum. If the precipitation is already sufficient to allow maximum growth an increase would be of no advantage. On the other hand neither would a decrease in moisture be reflected by tree growth if it did not fall below the optimum. Precipitation probably has not been a limiting factor in tree growth on the Oregon Coast during the post-Pleistocene, with the possible exception of Sitka spruce. It probably has been a factor in competition, however, because it has permitted moisture-loving species such as spruce and hemlock to flourish at the expense of Douglas fir and lodgepole pine. The last two species require less moisture but are less tolerant of shade than spruce and hemlock and cannot successfully compete with them where the amount of moisture is not a limiting factor. Lodgepole pine thrives chiefly on sandy areas along the shore where the shifting dunes discourage other species. After pine and various species of shrubs have formed a barrier against the winds and developed humus in the sterile beach sand, spruce and hemlock may enter and gradually replace them. Pine is the least tolerant for shade, while spruce and hemlock are the most so, with Douglas fir between in respect to this characteristic. Their moisture requirements, in order beginning with the greatest, are spruce, hemlock, Douglas fir, and lodgepole pine.

Sitka spruce seems to be the best climatic indicator of the four principal species recorded by their pollen in the bogs of this study. It has the most restricted geographic and climatic range, being confined chiefly to the coastal fog belt from northern California to Kodiak Island, Alaska. Douglas fir has the widest range, lodgepole pine next, followed by western hemlock. The latter extends much farther inland than spruce (Munns, 1938). Thus, the pollen profiles of pine and Douglas fir do not seem to be indicative of any climatic trends. The first invaded primary areas made available by the progress of the marine erosion cycle along a submerged coastline, and persisted until the edaphic conditions were modified sufficiently to permit its replacement by spruce and hemlock. Douglas fir owes its existence to the occurrence of periodic fires on the western slope of the Coast Range to the east of the spruce-hemlock association. Hemlock ranges farther east into the Coast Range than spruce, and its pollen profile may portray merely changes in relative abundance due to normal forest succession or destruction of other species. The depth of the Woahink Lake sediments is about three times that of Sand Lake bog and probably represents the greater portion of post-Pleistocene time. Its pollen profile, therefore, is of greater significance in the interpretation of climatic trends, although both profiles may be used where they seem to be contemporaneous.

The high proportion of spruce pollen in the lower five levels of the Woahink Lake bog suggest an initial wet climate as the ice was receding from regions farther to the north, or soon thereafter. A decline in spruce and an increase in hemlock to 10 meters suggest a possible decrease in precipitation during the period represented (Figure 1). A sharp decline in hemlock from 7 to 6.5 meters and less marked increment in spruce may not denote a climatic change. An increase in Douglas fir and lodgepole pine for the same levels suggests merely a relative fluctuation in abundance. Perhaps hemlock was destroyed by fire, permitting Douglas fir to gain a temporary advantage. As previously suggested, the 4-meter level in the Sand Lake bog may be concurrent with the 7-meter level of the other, as is shown by a less definite decrease and increase in hemlock and spruce respectively from 4 to 2.8 meters (Figure 2). An increase in hemlock from 5.5 to 3.25 meters in the Woahink bog and a converse decline in Douglas fir and pine indicates the recovery of this species from the hypothetical fire. A final decline in hemlock from 3.25 meters to the surface and an increase in spruce may reflect a slight increase in precipitation or changes in the forest composition due to unknown causes. The high proportion of lodgepole pine in the upper levels of the Sand Lake bog is a result of this species invading the bog surface, and the destruction of the spruce-hemlock forests by lumbering and burning in historic time. Lodgepole pine occupies the less desirable sites for cultivation and has little value as timber, and thus it is not removed by lumbering. This increases the relative abundance of its pollen in the peat, and distorts the pollen profiles. The climate for the time represented by the peat profiles evidently consisted of an initial wet period gradually succeeded by a slight decrease with fluctuations in moisture to a minimum, which has persisted to the present. A similar climatic trend has been interpreted from the pollen profiles on the east slope of the Coast Range in west central Oregon. Undoubtedly the proximity of the ocean has been instrumental in maintaining a more or less static climate during the post-Pleistocene, regardless of that farther inland.

IX. SUMMARY

Two peat bogs south of the limits of Pleistocene glaciation on the Oregon Coast have been dated as post-Pleistocene by the stage of the marine erosion cycle of a drowned shore line. The more recent series of geologic events culminating in postglacial bog formation are a Pleistocene uplift of the coastal plain, followed by stream trenching, which was further accentuated by lowering of the sea level during the glacial epoch, a drowning of the coast line as the sea level rose due to deglaciation, and the postglacial marine erosion cycle forming many lakes in the drowned valley mouths of streams entering the ocean.

Woahink Lake bog, which is almost twelve meters in depth, probably records all or most of postglacial forest succession, while Sand Lake bog, being only 4 meters deep, probably represents not more than half of post-Pleistocene time.

Both bogs lie within the spruce-hemlock forest climax, and the postglacial forests have apparently consisted chiefly of these species. Douglas fir and lodgepole pine have existed in much lower proportions, and with little exception have been of minor importance in the post-Pleistocene forests within range of pollen dispersal to the bogs. Sitka spruce has been generally predominant over western hemlock in the Woahink Lake region, while the reverse has been true for areas adjacent to Sand Lake.

The proximity of the Pacific Ocean undoubtedly has been a major factor in maintaining a static climate during the post-Pleistocene. The pollen profiles, however, suggest an initial wet period that became slightly drier to reach a minimum, which has persisted to the present.

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