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PALEOECOLOGY OF TWO PEAT BOGS IN SOUTHWESTERN BRITISH COLUMBIA

Henry P. Hansen

PALEOECOLOGY OF TWO PEAT BOGS IN SOUTHWESTERN BRITISH COLUMBIA [1]

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THIS IS the fifth of a series of studies by the author on fossil pollen of post-Pleistocene peat in the Pacific Northwest. Further studies are in progress, and eventually pollen analyses of bogs located within the major climax areas of vegetation in this region will be completed. The postglacial vegetational history and possibly climatic trends will be interpreted for the region as a whole from these data. The two bogs of this study lie near the mouth of the Fraser River valley. This area was covered by both the Admiralty and Vashon glaciations of the Pleistocene, the latter being generally correlated with the Wisconsin glaciation in the Middle West (Antevs, 1929). Much of the lower Fraser River valley has been considerably modified by postglacial activity of the river. The first bog is located about four miles southeast of New Westminster near the Pacific highway. It lies on the Surrey Terrace (Johnston, 1923), a remnant of glacial drift which apparently has not been disturbed by the shifting and erosion of the Fraser River (fig. 1). The depression in which

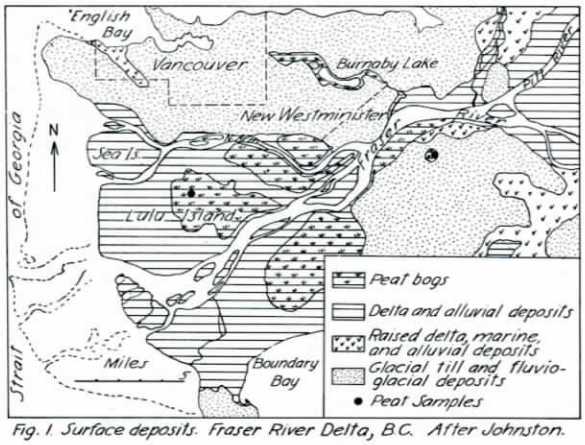

Fig. 1. Surface deposits. Fraser River Delta, B.C. After Johnston.

the bog has developed is either a kettle or merely a depression left in an irregular ground moraine. Thus it probably had its origin soon after the recession of the Vashon ice and records most of the postglacial forest succession which has occurred in adjacent areas. The total area comprises about forty acres and is several hundred feet above sea level. It is covered chiefly with an ericad associes, including Labrador tea (*Ledum groenlandicum*), bog laurel (*Kalmia polifolia*), cranberry (*Vaccinium oxycoccus*), and salal (*Gaultheria shallon*). Other plants present are sundew (*Drosera rotundifolia*), cloudberry (*Rubus chaemamorus*), hardhack (*Spiraea douglasii*), sedge (*Carex spp.*), bracken fern (*Pteridium aquilinum*), *Polytrichum sp.*, and *Sphagnum* sp. Lodgepole pine (*Pinus contorta*) is invading the margins of the bog, and in several places where it has been burned, western birch (*Betula occidentalis*) seems to be the chief arboreal invader along with fireweed (*Epilobum angustifolium*). The peat is being removed for commercial purposes, and in a few years all the virgin aspects of the bog will have been removed. The depth of the bog in the area of sampling is 4.25 meters. The lower quarter meter consists of brown limnic peat, overlying raw, glacial sand. This grades upward into brown fibrous peat to the 2.5 meter level, from which point to the surface it consists of almost pure Sphagnum moss, with a mixture of ericaceous shrubs in the upper half meter. A layer of charred peat occurs at 2.75 meters. The absence of silt throughout indicates that the bog has not been flooded by incoming streams. Volcanic ash crystals are present from 2.75 to 2.25 meters, being most abundant at the 2.5 meter level. The ash usually occurs as a single, well-defined layer in the bogs of the Puget Sound region, (Rigg, 1938; Hansen, 1938). It also occurs as a layer in a montane bog in central Washington and in bogs in eastern Washington and northern Idaho (Hansen, 1939a, 1939b, 1939c). The stage of hydrarch succession at the time of eruption seems to be the controlling factor as to whether the ash is preserved as a layer or dispersed. As a layer it is usually found within the sedimentary peat or occasionally within sedge peat. The compactness of these two types apparently prevents the ash from being dispersed vertically. In this bog the ash is within the sphagnum peat stratum, which suggests that it fell on a Sphagnum moss cover and was washed downward by rain. The ash is an important chronological indicator and aids greatly in the correlation of postglacial forest succession in the various climax areas in the Pacific Northwest. It seems probable that the ash came from the same eruption, but petrographic studies will have to be made to verify this assumption.

The other bog is one of several covering a large portion of Lulu Island, which is separated from Vancouver, British Columbia, by the North Arm, and bounded on the south by the main channel of the Fraser River (fig. 1). Lulu Island is composed chiefly of delta deposits laid down during the post-Pleistocene by the Fraser River debouching into the Strait of Georgia (Johnston, 1921). The westernmost edge of the bog lies within five miles of saltwater. The depression in which the peat has accumulated apparently had its origin in abandoned river channels, formed as the river was changing its course upon the upbuilding delta. The ponding of water was further increased by the formation of levees along the river, resulting in a large, shallow body of water. During its earlier development, the bog was subjected to periodic inundation as is evidenced by the thick deposit of silt underlying the peat and its presence throughout much of the peat. The surface is only about fifteen feet above sea level and may have been inundated by saltwater at times, resulting in the development of saltmarsh vegetation. This is suggested by the presence of saltmarsh plant pollen

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in several levels. The early shifting of the distributaries of the Fraser River upon its delta and the periodic inundation by floods and tidewater probably reassorted or removed earlier deposited pollen-bearing sediments, so that the pollen spectra may not present a true or complete picture of early post-glacial forest succession in the adjacent areas. There seems to be some correlation, however, with the pollen spectra of the Westminster bog.

The virgin aspect of the surface has been modified by drainage, grazing, cultivation, and fire, but there are large areas that have retained their natural conditions. These areas support a typical bog-ericad associes consisting of Labrador tea, bog laurel, bog rosemary (*Andromeda polifolia*), blueberry (*Vaccinium canadense*), bilberry (*V. uliginosum*), cranberry, and salal. Some Sphagnum moss is present, but *Polytrichum* sp. is more abundant, especially on burned areas. The bog is being invaded by dense stands of lodgepole pine, which had a heavy crop of staminate cones at the time they were observed by the writer. In some areas the lodgepole has been burned, apparently in view of restoring the slight amount of grazing which existed before its invasion. These areas are being rapidly invaded by thick stands of western birch which have not yet produced staminate catkins. Hardhack is abundant along the drainage ditches, while cloudberry covers large areas with the ericads. Sampling by the Canadian Geological Survey shows that the bog is uniform in depth over much of its area and does not exceed twenty-two feet. The bog, or pollen-bearing sediments, is underlain with raw, coarse sand, grading upward into silt, and at 4.5 meters changing into blue clay. This in turn begins to grade into gray limnic peat at 3.75 meters, followed by brown limnic peat with fibers present. At 2.25 meters the limnic changes into brown fibrous peat, which is present to the surface. Neither a volcanic ash layer nor ash crystals were noted, although the former occurs in a bog in Vancouver, British Columbia. The presence of considerable silt up to the 2 meter level would make its differentiation difficult if it were present. The torrential rains which usually follow volcanic activity may have flooded the island and mixed the ash with silt, or carried it away. The area of the bog comprises some 8,000 acres.

Samples were secured with a Hiller peat sampler at quarter meter intervals in both bogs. In preparation for study, the peat was boiled in a weak solution of potassium hydrate, washed several times, centrifuged, stained with gentian violet, and mounted in glycerin jelly. The author is cognizant of newer methods devised for the preparation of peat for pollen analysis, but the peat in the Pacific Northwest contains an abundance of pollen, and there seems to be no necessity for its concentration by some of the later methods. From 106 to 604 pollen grains were identified at each level in both bogs. Pollen was more abundant in the Westminster bog than in the other. In many of the levels much of the pollen identified was of species existent during various hydrosere stages or in associes near the margin of the bog and are not indicators of forest succession. The number was not used in the computation of percentages, but the numbers observed at each level are listed in the tables, because their presence is indicative of hydrarch succession (table 1, 2). Those species represented by less than 1.5 per cent of the total at any level are listed as 1 per cent in the tables.

Forests in adjacent areas.—The lowland areas adjacent to the bogs and probably within the radius of pollen dissemination to the bogs may be classified as being within the Humid Transition Life Zone as

Table 1. *Percentages of fossil pollens. New Westminister bog.*

Depth in meters:	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	.75	.50	.25	Top
Pinus contorta	75	77	69	60	44	30	36	12	11	8	6	9	7	6	7	8	5	4
P. monticola	10	4	3	5	4	5	4	1	1	2	4	2	2	4	4	3	5	8
Pseudotsuga mucronata	1	..	2	3	5	1	13	44	23	23	22	23	30	33	30	37	34	28
Tsuga heterophylla	1	1	1	2	3	..	9	31	49	44	44	48	42	37	35	28	36	41
Picea sitchensis	4	6	14	23	35	57	34	4	4	5	7	10	12	13	17	15	16	17
Abies grandis	4	2	7	5	5	5	2	3	5	14	13	8	5	6	5	6	3	1
Gramineae	3	10	3	2	3	1	2	3	1	1	1	..	1	..	1	1	..	..
Compositae	..	..	..	..	..	..	..	1	1	1	..	..	..	..	..	..	..	..
Betula	2	..	1	..	1	1	..	1	4	1	3	..	1	1	1	2	1	1
Chenopod-Amaranth[a]	3	..	..	..	..	..	..	..	32	1	..	..	..	..	..	..	..	..
Alnus[a]	2	40	42	33	23	12	24	310	140	96	82	73	23	34	19	44	27	48
Acer[a]	2	..	2	3	1	..	..	2	1	7	1	3	..	..	..	..	1	..
Salix[a]	2	25	30	16	7	3	4	4	3	1	..	..	..	..	..	..	..	..
Fraxinus[a]	..	..	..	..	..	..	..	..	1	4	3	..	..	..	..	..	..	..
Cyperaceae[a]	1	1	29	13	18	6	44	13	14	18	19	8	2	..	1	1	1	3
Ericaceae[a]	12	..	..	..	4	..	4	..	8	24	20	32	8	8	16	16	28	42
Nymphaea polysepala[a]	..	..	3	..	9	..	..	15	3	4	..	..	..	..	..	..	..	..
Typha latifolia[a]	..	2	10	..	2	..	..	5	1	3	..	5	4	..	3	..	..	..
Drosera rotundifolia[a]	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	20	8
Total pollens counted	159	274	296	240	309	296	256	604	476	406	310	346	286	322	333	295	292	351

[a] Number, and not computed in percentages.

TABLE 2. *Percentages of fossil pollens. Lulu Island bog.*

Depth in meters:	5	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5	Top
Pinus contorta	67	66	62	50	46	33	28	30	40	43	67
P. monticola	8	8	10	13	16	15	11	9	7	5	2
Pseudotsuga mucronata	..	1	1	5	1	4	12	10	6	3	3
Tsuga heterophylla	7	7	5	6	7	19	33	34	37	26	17
Picea sitchensis	8	13	15	16	18	14	10	8	2	10	4
Abies grandis	9	5	6	10	12	12	4	7	4	9	7
Gramineae	..	..	1	..	..	1	1	..	1	2	..
Betula	1	..	..	..	..	2	1	1	2	1	..
Chenopod-Amaranth[a]	1	..	..	..	6	3	21	4	..	..	..
Alnus[a]	2	..	1	4	1	19	10	19	58	13	15
Acer[a]	..	..	1	..	..	..	1	1	..	..	1
Fraxinus oregana[a]	..	..	..	..	..	..	..	..	..	..	1
Cyperaceae[a]	2	4	..	1	1	14	90	1	6	..	..
Ericaceae[a]	8	..	..	..	..	..	..	80	40	16	220
Nymphaea polysepala[a]	..	..	..	..	..	..	..	..	1	1	..
Typha latifolia[a]	12	8	4	4	12	104	40	20	12—	..	4
Drosera rotundifolia[a]	..	..	..	..	..	..	..	..	4	4	4
Total pollens counted	144	142	106	129	129	247	301	341	272	155	396

[a] Number, and not computed in percentages.

defined by Merriam (1898), if his classification were used to include this part of Canada. The forests of this area exhibit much the same physiognomy as those of the Puget Sound region farther south. The annual precipitation at Vancouver, British Columbia, is about 60 inches. According to Thornthwaite's classification of the climates of North America, this region is characterized as having a humid, microthermal climate with adequate precipitation at all seasons (Thornthwaite, 1931). It borders on the wet, microthermal zone at slightly higher elevations to the east. This area lies within the hemlock-cedar formation of the Coast Forest, according to Clements' classification of North American vegetation climaxes (Weaver and Clements, 1938). In this formation Douglas fir (*Pseudotsuga mucronata*), one of the chief dominants, is a subclimax species because of the intolerance of its seedlings for shade. Those of western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) thrive on the forest floor, and if normal forest succession is not interrupted, these species will gradually crowd out Douglas fir. This may result in a climax forest of hemlock and cedar, with old and mature Douglas firs scattered throughout (Hofmann, 1924). The Canadian Forest Service designates the forest in this part of British Columbia as a Douglas fir-red cedar type, with these species forming at least 50 per cent of the stand and Douglas fir predominant (Whitford and Craig, 1918). This type makes its greatest development where the annual precipitation is between 50 and 60 inches. Associated with these species, and occurring in order of their relative importance, are western hemlock, Sitka spruce (*Picea sitchensis*), white fir (*Abies grandis*), lovely fir (*A. amabilis*), western white pine (*Pinus monticola*), and lodgepole pine. Western hemlock occurs almost everywhere throughout the type, increasing in prominence at higher elevations and on less favorable sites. Both firs are confined to virgin stands, the white fir at the lower and the lovely fir at the higher elevations. Sitka spruce occurs in this type along the valley bottoms and close to the shore, and it is seldom found at more than 1,000 feet above sea level. Western white pine is not very abundant, and it occupies knolls or open, well-drained areas because of its intolerance for shade. Lodgepole pine may be found invading mature bogs, or in areas where the soil has been much disturbed. The more important deciduous trees in this area include red alder (*Alnus oregona*), cottonwood (*Populus trichocarpa*), western birch, broad-leaf maple (*Acer macrophyllum*), and several species of willows (*Salix scouleriana, S. hookeriana,* and *S. sitchensis*). Along the shore, in areas that are subjected to inundation by saltwater, or in marsh areas whose water table is controlled by adjacent saltwater, may be found saltmarsh plants such as arrow grass (*Triglochin maritima*), saltbush (*Atriplex hastata*), and samphire (*Salicornia ambigua*), and several species of sedge.

POSTGLACIAL FOREST SUCCESSION.—The pioneer forests to invade areas adjacent to the bogs consisted chiefly of lodgepole pine. In the lowest two levels of the Westminister bog this species records 75 and 77 per cent, and in the lowest level of the Lulu Island bog a percentage of 67 occurs (fig. 2, 3). The early invasion by lodgepole pine is similar to that indicated by pollen analysis of bogs in other climax areas in the Pacific Northwest (Hansen, 1938, 1939a, 1939b). In both bogs there is a decrease of lodgepole from the lower levels. In the Westminister bog an extremely sharp decrease from 77 per cent at 4 meters to 12 per cent at 2.5 meters occurs. This is followed by a more gradual decrease to 4 per cent at the surface. The other bog exhibits gradual decrease from the lowest level to 28 per cent at 2 meters, from which level it shows an increase to the surface where it records 67 per cent, the same as at

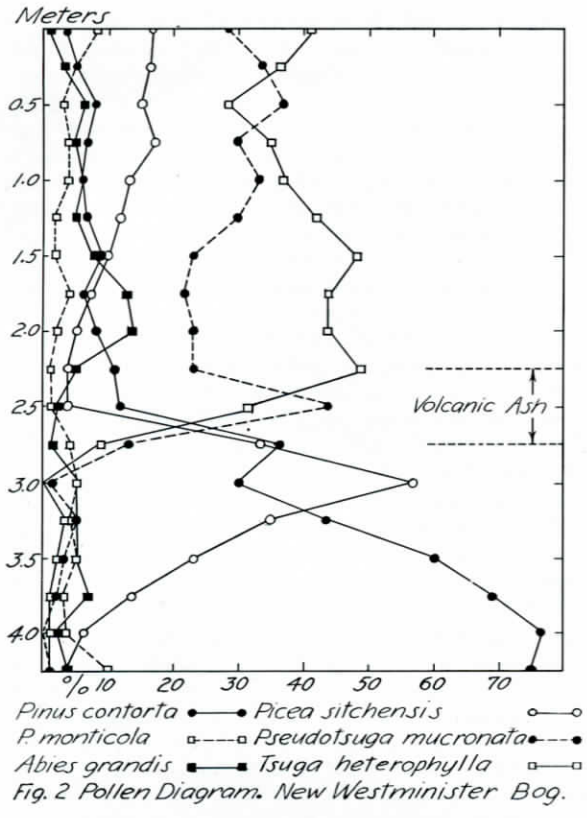

Fig. 2 Pollen Diagram. New Westminister Bog.

the lowest level. This increase in the upper part of the bog reflects the invasion of lodgepole on the bog and perhaps the remoteness of other species, as there are few trees on the island. The area of the island and adjacent delta lands comprises more than one hundred square miles, most of which has not been forested because of the unstable physiographic and edaphic features. The dearth of pollen of other trees raises the question as to the distance that anemophilous forest tree pollen is dispersed. The direction of prevailing winds during pollen-shedding may also be a factor in limiting the representation of other species in the peat. The winds blow chiefly from off the water during the period of anthesis, and probably do not carry much pollen. The inland forests leeward to the bog would not be recorded to any great extent.

Sitka spruce plays a more important rôle in postglacial forest succession in this area than in other areas in which bogs have been studied. In the Westminister bog it shows a sharp increase from 4 per cent in the lowest level to 57 per cent at 3 meters. It then decreases to 4 per cent at the 2.5 and 2.25 meter levels and gradually increases again to record 17 per cent at the surface. In the Lulu Island bog spruce reaches its maximum of 18 per cent at 3 meters, from which it decreases to 4 per cent at the surface. The presence of 57 per cent spruce and 30 per cent of pine pollen at the 3 meter horizon in the Westminister bog indicates a definite spruce-pine period with a predominance of the spruce. This would seem logical, because lodgepole pine matures earlier and is a more prolific pollen-producer than spruce; so if pine were as abundant as spruce, it would probably record a higher percentage of pollen. At Glacier Bay, Alaska, Sitka spruce is the pioneer conifer to invade areas recently vacated by receding valley glaciers (Cooper, 1939). These areas are initially invaded by mosses and prostrate willows, which in turn are succeeded by alder and shrubby willows before the spruce invasion. The final stage has spruce and western and mountain hemlock (*Tsuga mertensiana*) as its dominants, although it would seem doubtful that forest succession has reached a climax in such a short time. Lodgepole pine seedlings are present, but this tree apparently has not been important in pioneer forest succession. Near Kodiak, in southwestern Alaska, Sitka spruce is the pioneer forest tree to invade areas which apparently have not been forested during postglacial time (Griggs, 1934). Pollen analyses of two bogs situated within the edge of the spruce-hemlock forest near Kodiak show a significantly low percentage of spruce pollen up to the 3-foot level, above which samples were not obtained because of the mushy character of the peat (Bowman, 1934). This is believed to indicate that the edge of the forest at Kodiak had moved westward for a considerable distance during the time required for the accumulation of the upper three feet of peat. The minor rôle of lodgepole pine in the pioneer forests in both areas in Alaska is significant, in view of its invasion of other recently deglaciated areas in

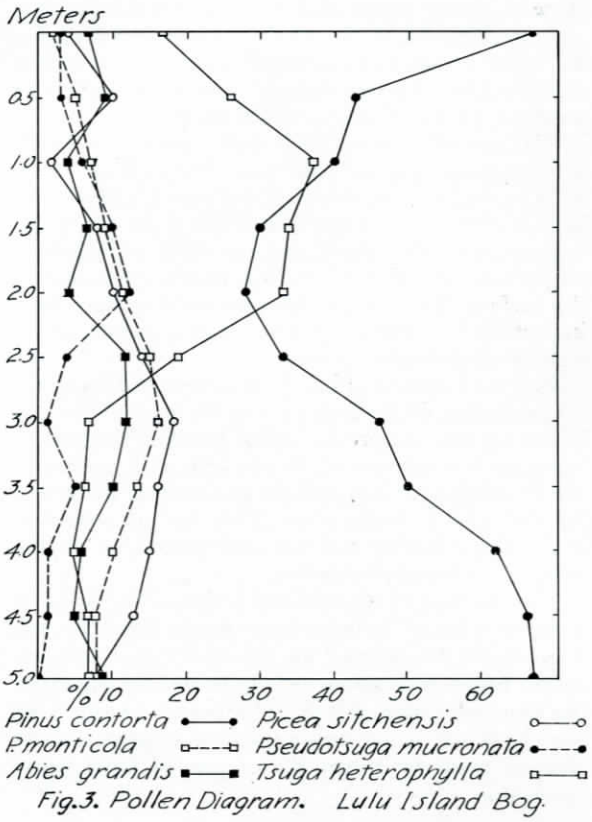

Fig. 3. Pollen Diagram. Lulu Island Bog.

postglacial time. The analysis of bogs in the spruce-hemlock forest on the Olympic Peninsula may shed some light on the postglacial history of lodgepole pine in a spruce-hemlock climax formation.

As postglacial time progressed, the spruce-pine associes was gradually replaced by Douglas fir and hemlock, the latter being probably western hemlock. Both species are present in the lower levels of the Westminister bog. Douglas fir rapidly increases from 1 per cent at 3 meters to 44 per cent at 2.5 meters, while hemlock increases from none at 3 meters to 49 per cent at 2.25 meters to supersede Douglas fir (fig. 2). Douglas fir decreases from its maximum at 2.5 meters to 23 per cent at the next level, and hemlock remains dominant to the 0.75 meter level where it decreases at 0.5 meters and increases again to the surface. In the Lulu Island bog, Douglas fir reaches its maximum at 2 meters with only 12 per cent, while hemlock reaches 33 per cent at the same level to supersede lodgepole pine, and continues to increase slightly to 37 per cent at 1 meter. Lodegpole pine in turn increases to supersede hemlock at the same level. The recent increase of pine, however, is due to its invasion of the bog and is not representative of the adjacent forests. Hemlock records a final decrease to 17 per cent, while Douglas fir shows only 3 per cent at the surface. The successional relationship of Douglas fir and hemlock as shown by pollen analysis is similar to that shown by their present development in the Puget Sound region as previously discussed. Pollen analyses of bogs near Tacoma and Seattle, Washington, show the same postglacial successional relationship and development of the subclimax status of Douglas fir, while a somewhat similar relationship is shown to have existed in postglacial forest succession in northern Idaho (Hansen, 1938, 1939b).

Western white pine is not well represented in the Westminister bog, although it is present in all levels. It is second in abundance to lodgepole pine in the lowest level. In the Lulu Island bog it shows a higher frequency throughout and records a maximum of 16 per cent at 3 meters. It decreases to 2 per cent at the surface. This species does not seem to have been important in forest succession in this region where it is not abundant at present.

Pollen of white and lovely fir is grouped together, although that of the former is much more abundant. These species are present in all levels of both bogs, reaching a maximum of 14 per cent at 2 meters in the Westminister bog and 12 per cent at the 3 and 2.5 meter levels in the other. They are not abundant in the Coast Forest and were not prominent during postglacial forest succession.

The absence of western red cedar pollen is to be noted because of its importance in the Coast Forest. It probably has played an important part in more recent forest succession, as is indicated by the existing hemlock-cedar climax. The pollen of this species, however, is not well preserved in peat, and its absence tends to distort the picture of later forest succession.

The most important species of broadleaf represented is alder, whose pollen was not used in the computation of percentages because of its local occurrence as a seral unit. It reaches its greatest abundance of 310 at 2.5 meters in the Westminister bog and 58 at 1 meter in the other (table 1, 2). Western birch pollen occurs in limited amounts in many levels of both bogs. The presence of Chenopod-Amaranth pollens in several levels in both bogs is of some significance. In the Lulu Island bog their presence from the 3.5 to the 1 meter level suggests the development of a saltmarsh plant community near or on the bog. The greatest amount of sedge pollen was also noted at these levels, some of which may represent saltmarsh sedges. In the Westminister bog 32 pollen grains of this group occur at 2.25 meters, but it is doubtful whether salt water ever reached this bog. It seems likely that the pollen came from saltmarshes along the estuary of the Fraser River.

Climatic considerations.—As stated in previous papers, it does not seem expedient to draw definite conclusions in regard to climatic fluctuation from forest succession in the Pacific Northwest, as interpreted from pollen analysis. It is a question whether postglacial forest succession has been more a result of climatic change or largely normal forest succession. The extensive geographic and climatic ranges of the species concerned, their multiple associations and faciations, overlapping of their ranges, their adaptability to extremes of moisture and temperature, their relative tolerance of shade, their edaphic requirements, their differences in age of maturation and longevity, plus the interrelationships of all these factors tend to discourage one from being too dogmatic in his conclusions. Lodgepole pine grows from sea level to 8,000 feet in elevation, in areas of precipitation from 10 to 75 inches per annum, in regions of wide seasonal range in temperature and in others of slight seasonal variation, on bogs and sterile sand, and in many different associations. It is possible, however, that the coastal form of this species differs from the interior form, and therefore indicates a more humid climate. The other species also exhibit as wide a range with respect to many of these factors. The presence of a species in one area may indicate a different climate than its presence in another, depending upon the ecological relationships of the species with which it is associated.

Cognizant of these facts, the writer tentatively deduces that the pioneer forests of lodgepole pine suggest an initial cool and damp period, but probably drier than the present marine climate. The proximity of the ocean to this area probably made it damper than areas farther inland. This period was followed by one of increasing humidity and temperature, as evidenced by the increase of spruce to 57 per cent at 3 meters in the Westminister bog. Sitka spruce is perhaps more restricted in its climatic range than any of the other species here concerned and should be one of the better climatic indicators. It reaches its maximum development in the fog belt along the North Pacific Coast. The advent, rapid in-

crease, and dominance of Douglas fir and hemlock mark a third period of decreasing humidity and temperature to a degree which has existed to the present. Pollen analyses of bogs farther south in the Puget Sound region seem to offer evidence for similar conclusions. Fuller (1935) believes a similar trend occurred in the Mid Lake region with respect to temperatore, while Von Post (1930) reaches similar conclusions for European postglacial climatic trends.

SUMMARY

Pollen analyses of two post-Vashon bogs in southwestern British Columbia show that the pioneer postglacial forests consisted largely of lodgepole pine, suggesting an initial cool and damp period.

This was followed by a spruce-pine forest with a predominance of spruce, indicating an increase in moisture and temperature.

A third period of decreasing moisture and temperature is marked by the increase and dominance of Douglas fir and hemlock, which has existed to the present.

The method of formation of Lulu Island, its physiographic and edaphic instability, its position in relation to winds and adjacent forests, and plant succession on the island and bog are responsible for an inaccurate representation of nearby forests by their pollen as preserved in the peat. The Westminister bog, however, probably records a fairly accurate representation of adjacent forests.

Climatic interpretations are tentative but essentially agree with those of pollen analyses of other bogs in the Pacific Northwest.

Department of Botany,
Oregon State College,
Corvallis, Oregon

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