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POLLEN ANALYSIS OF THREE BOGS ON VANCOUVER ISLAND, CANADA*

By HENRY P. HANSEN, *Dean of the Graduate School, Oregon State College*

(*With four Figures in the Text*)

Introduction

Peat sections were obtained from three bogs located along the southern half of the east coast of Vancouver Island, Canada (Fig. 1). The most northern is near Black River, about 22 miles north-west of Courtenay and 4 miles inland from the coast. The second bog is located about 2½ miles inland from Qualicum Beach about 30 miles north-west of Nanaimo. The third and most southern bog is located at the north end of Langford Lake

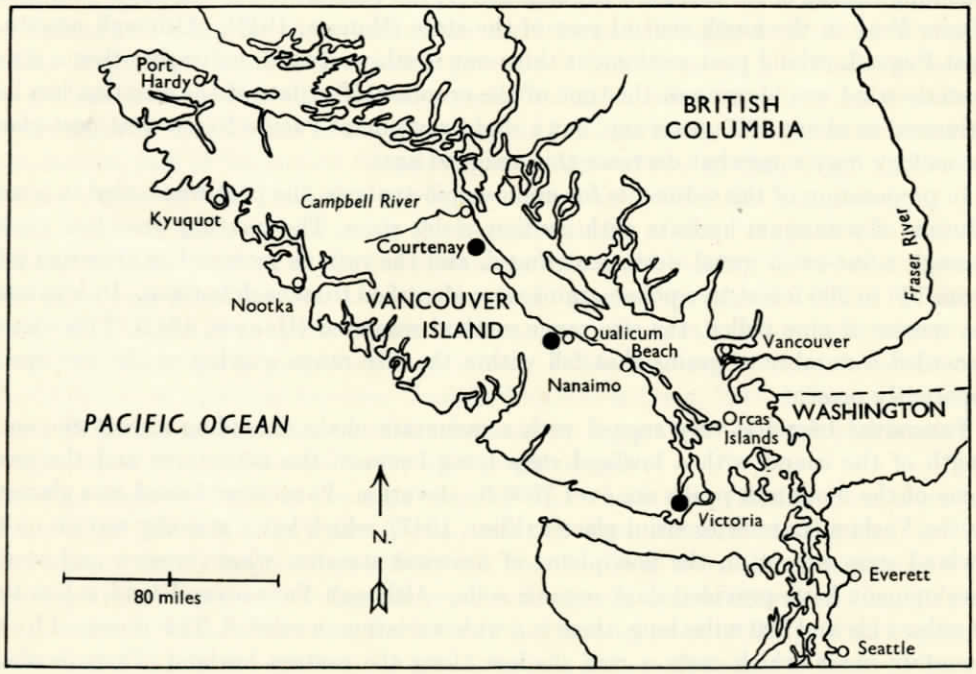

Fig. 1. A generalized map of Vancouver Island showing location of bogs by black dots.

about 8 miles west of Victoria. The two distal bogs are about 135 miles apart. The depths of the organic sediments in the area of sampling are 7·0, 6·4 and 8·0 m. respectively. The Black River bog has developed about a small lake apparently formed by disruption of drainage by glacial deposits. Hydrarch succession in the area of sampling is in the swamp stage, with no evidence of *Sphagnum* bog development. Sections were taken a few yards

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from the water's edge at 2 dm. intervals, and consisted of about 3 m. of limnic peat and 4 m. of fibrous sedge peat. The bog near Qualicum Beach is a *Sphagnum* type with a shrub cover composed chiefly of Labrador tea (*Ledum groenlandicum*) with a few lodgepole pine (*Pinus contorta latifolia*). The most southern section was taken from a swampy area near the water's edge, and consisted of about 3 m. of limnic peat and 5 m. of fibrous sedge peat. All three sections were taken down to underlying sand and gravel and probably represent most of the time since deglaciation of the east coast of Vancouver Island.

Volcanic glass fragments were noted in all sections. In the Black River section glass was noted at 2·8 and 3·0 m.; in the Qualicum Beach section, at 2·2 and 2·4 m.; and in the Langford Lake column, at 3·2 m. Glass fragments were sparsely scattered in the peat matrix, but easily recognizable. Volcanic ash occurs as a well-defined stratum in bogs on Orcas Islands a few miles to the east, but only scattered fragments were found in a peat section near New Westminster, British Columbia (Hansen, 1942, 1943). The volcanic ash stratum is present in all post-glacial organic sedimentary columns in eastern Washington, becoming thicker north-eastward in the state. It has been ascribed to a single eruption of Glacier Peak in the north central part of the state (Hansen, 1947). Although present in most Puget Lowland peat sections, it thins out south-westward, indicating that a strong westerly wind was blowing at the time of the eruption. The date of the eruption has been estimated at about 6000 years ago, but a slight revision of Pacific North-west post-glacial chronology may somewhat decrease this assigned age.

In preparation of the sediments for microscopic analysis, the peat was boiled in a weak solution of potassium hydrate with gentian violet stain. The mixture was then washed through a fine-mesh metal sieve, centrifuged, and the residue mounted in glycerine jelly. From 100 to 200 forest tree pollen grains were identified from each horizon. In separating the species of pine pollen, the size range method was used (Hansen, 1947). This method discarded a number of grains that fell within the size range overlap of the two species apparently present.

Vancouver Island is very rugged with a mountain chain extending almost the entire length of the island with a lowland strip lying between the mountains and the coast. Some of the mountain peaks are over 7000 ft. elevation. Vancouver Island was glaciated by the Vashon (Late Wisconsin) glacier (Flint, 1947), which left a gravelly terrain on the lowland strip except on the floodplains of drowned streams, where erosion and swamp development have provided dark organic soils. Although Vancouver Island is less than 80 miles wide and 300 miles long, there is a wide variation in rainfall. This is caused by the mountain chain which casts a rain shadow along the eastern lowland. There is also a differential in rainfall along the eastern side from south to north. At Victoria at the south end of the island, the mean annual precipitation is about 27 in., while at Port Hardy near the north end of the island, but on the east side, it is about 70 in. At Campbell River, the nearest station to the site of the Black River bog, the annual average rainfall is about 50 in., and at Parksville, near Qualicum Beach, it is about 30 in. The increase in precipitation northward along the east coast of Vancouver Island is reflected in both the composition of the forests and the pollen profiles, as will be shown later. Along the west coast near sea-level, the average annual precipitation is over 100 in. at most stations, with 117 in. at Kyuquot in the northern part and 116 in. at Port Nititat directly across the island from Nanaimo where it is about 36 in.

Forests of Vancouver Island

The composition of the forests and the distribution and concentration of the species thereof are controlled largely by the precipitation, elevation and soil. There are eleven species of conifers and nine species of broadleaf trees on Vancouver Island, in addition to several broadleaf species of questionable arborescent stature. The most abundant and widespread conifers are western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga taxifolia*), and western red cedar (*Thuja pliata*). While these species range over the entire island they may occur on favourable local sites only, where the soil, terrain, exposure or climate are generally favourable. Western hemlock probably has the most continuous distribution of the three species (Whitford & Craig, 1918). Douglas fir has its greatest concentration on the southern half and along the eastern side of the island. Along the south-eastern tip and eastern lowland for some distance northward, Douglas fir is a climax species because the dry summers and the low annual rainfall are unfavourable for western hemlock. Farther north and inland, Douglas fir is probably subclimax and has persisted as a result of periodic fire. Inland and along the west coast of the northern half, Douglas fir is not so abundant because of the high precipitation which prevents it from competing with the moisture-loving hemlock and cedar. Also this area probably has been less subject to fire because of the wet climate. In addition to the sparseness of hemlock in the lowland areas along the south-eastern part of Vancouver Island, the occurrence of two species, Oregon white oak (*Quercus garryana*) and madrona (*Arbutus menziesii*), reflect the comparatively dry climate. Both of these species reach the northern limits of their range in the lowlands bordering the Georgia Straits. Oak is most abundant in the vicinity of Victoria, where it forms small pure stands as well as occurring singly on the dry, gravelly knolls. It also is mixed with Douglas fir in sparse stands. Oak ranges as far north as Courtenay, becoming less and less abundant as precipitation increases. It has been reported on the north-west end of Vancouver Island on Quatsino Sound (Whitford & Craig, 1918). Oregon white oak reaches its maximum abundance and development on the gravelly outwash plains south of Olympia and in the Willamette Valley of western Oregon.

Another important tree in the area of study and which has evidently been more important in the past is lodgepole pine (*Pinus contorta*). Both the stunted coast form and the taller, inland variety *latifolia* apparently are present. It is most abundant on the well-drained gravelly benches bordering the coast and becomes sparser inland. Lodgepole pine has undoubtedly been favoured by fire both in the past and more recently. With respect to the location of the three bogs of this study, lodgepole is more abundant in forests adjacent to the Qualicum Beach bog. Three species of fir occur on Vancouver Island. Lowland white fir (*Abies grandis*) occurs most abundantly on the coastal lowland, while alpine fir (*A. lasiocarpa*) is sparingly found at higher altitudes farther inland, near timberline. Silver fir (*A. amabilis*) has a wider range than the other two and is distributed inland from the coast at middle altitudes. In the forests adjacent to the bogs, lowland white fir is most abundant. Another species represented by its pollen in the sedimentary columns is Sitka spruce (*Picea sitchensis*). It occurs only sparingly along the south-eastern part of the island along the inlets. It becomes more common along the coast of the northern half and is very abundant at the northern part and along the west coast. Sitka spruce is a moisture-loving tree and thrives only in the moist lowlands along the inlets and bays. Western white pine (*Pinus monticola*) is widely distributed on Vancouver Island, but is not particularly

abundant. It occurs on the better-drained light soils on the slopes of the river valleys and bays and inlets, and is appreciably represented in the sedimentary columns. At higher elevations near timberline, mountain hemlock (*Tsuga mertensiana*) and Alaska cypress (*Chamaecyparis nootkatensis*) occur sparingly. The former is represented by its pollen sporadically and sparsely through the peat sections.

Two other common borderleaf species are Oregon alder (*Alnus oregona*) and big-leaf maple (*Acer macrophyllum*). Both of these species prefer the moister sites on alluvial soils where they temporarily replace the coniferous forests after fire. Other broadleaf species observed in the area of study include Oregon ash (*Fraxinus oregana*), western birch (*Betula occidentalis*), aspen (*Populus tremuloides*), black cottonwood (*P. trichocarpa*) and cascara (*Rhamnus purshiana*). Both ash and aspen are restricted to the south-eastern tip of the island. Cottonwood is abundant on the floodplains, and birch is found occasionally in the upland forests on better-drained soils. The foregoing description is brief, but it provides a basis for the discussion of the post-glacial forests with respect to interpretation of succession and climate.

POST-GLACIAL FOREST SUCCESSION

In all sections lodgepole pine is predominantly recorded in the lower levels, with 74, 80, and 95% at the bottom in the northern, middle and southern sections respectively (Figs. 2–4). Although lodgepole pine probably is over-represented by its pollen in peat

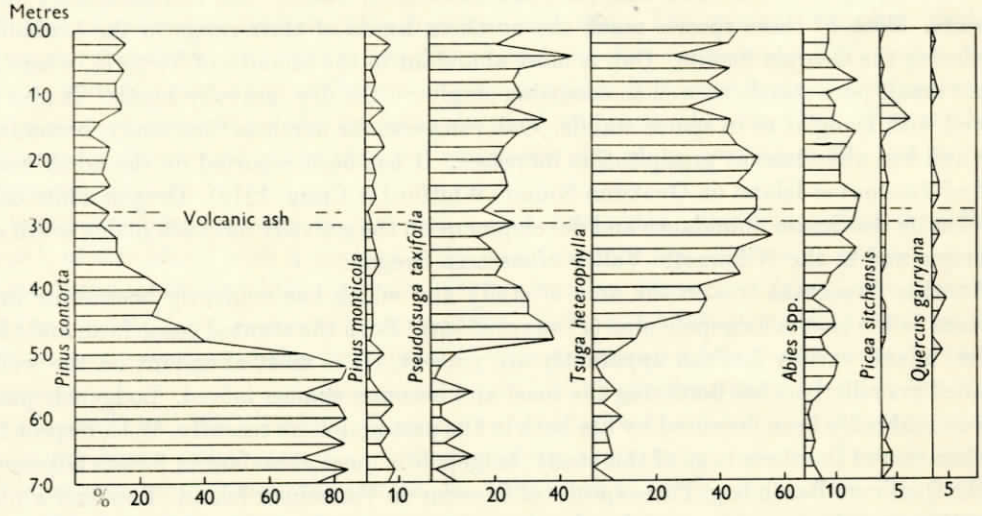

Fig. 2. Pollen diagram of bog near Black Creek. The abundant precipitation in the region is manifested in the high proportions of western hemlock.

sections, these proportions are sufficiently high to denote predominance in the area when the earliest pollen-bearing sediments were laid down. This is consistent with the pollen records of bogs throughout the Puget Lowland and in general throughout the Pacific North-west, where pollen analysis reveals that lodgepole pine was an important if not predominant species in early post-glacial forests, even beyond the limits of glaciation (Hansen, 1947). Pollen analysis of peat sections from bogs on Orcas Islands, Lulu Island at the mouth of the Fraser River and near New Westminster in British Columbia, shows

that 65% or more of the pollen in the lowest levels is that of lodgepole (Hansen, 1940, 1943). Lodgepole pine was also abundant or predominant in the early post-glacial, pioneer forests of the Glacier National Park region, western and central Alberta, and along the Alaska Highway in north-eastern British Columbia (Hansen, 1948, 1949*a*, 1949*b*, 1950).

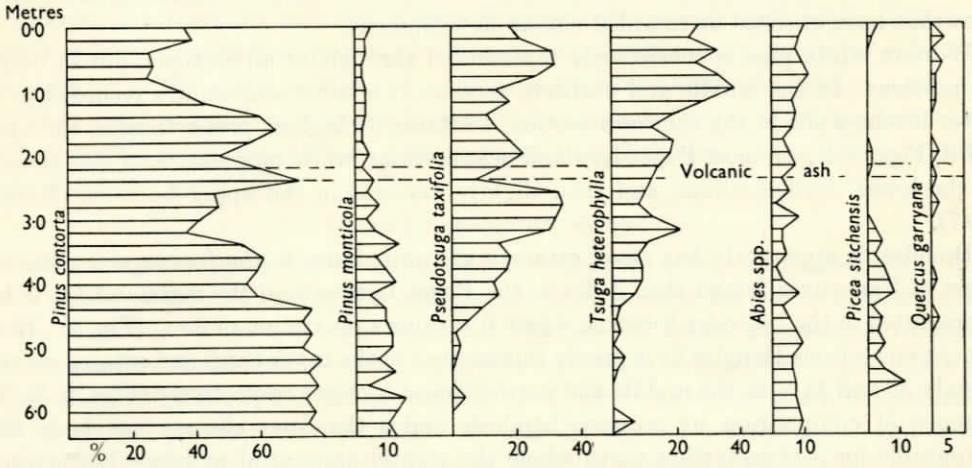

Fig. 3. Pollen diagram of bog near Qualicum Beach. Lesser rainfall than farther north is reflected by the lower proportions of hemlock.

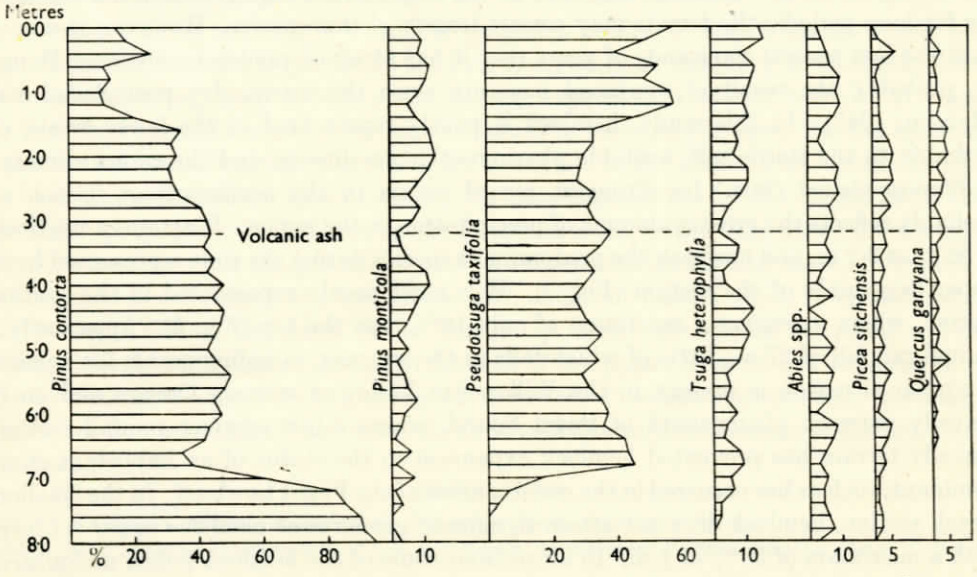

Fig. 4. Pollen diagram of bog at north end of Langford Lake, near Victoria. The drier climate than farther north is expressed by less hemlock and more Douglas fir and oak.

Its importance in early post-glacial forests probably can be attributed to its prolific seed production, early seed-bearing habit, its ability to thrive on sterile mineral soils, and in general its wide ecologic amplitude.

In the northernmost section, lodgepole maintains high proportions upward to about 5 m., and then rapidly declines and fluctuates between 4 and 16% from 3·6 m. to the top

(Fig. 2). In the Qualicum Beach section, pine maintains higher proportions than the other two throughout, with a minimum of 25% at 0·8 m. (Fig. 3). In the southernmost section, lodgepole persists in proportions between 50 and 31% throughout most of its profile (Fig. 4). The recorded predominance of lodgepole in forests adjacent to the Qualicum Beach bog throughout much of the time represented may reflect the influence of recurring fires that have checked or retarded climax development.

Western white pine is consistently represented throughout all sections, but in limited proportions. In the middle and northern sections it is most abundantly recorded in the lower levels, while in the southern section it attains its highest proportions in the upper third (Figs. 2–4). In most Puget Lowland peat sections, white pine makes its best showing in the lower third, declines, and then slightly expands in the upper horizons (Hansen, 1947).

Douglas fir apparently has never attained the abundance in the forests along the east coast of Vancouver Island that it did in the Puget Lowland on the mainland. It is best represented in the bog near Victoria, where it attains a maximum of 58% (Fig. 4). In the other two sections Douglas fir is poorly represented in the lower third and attains maxima of only 35 and 44% in the middle and northernmost sections respectively (Figs. 2, 3). The absence of competition by western hemlock under the drier climate has been more favourable for it than farther north where the greater amount of moisture has favoured hemlock.

Western hemlock is a climax dominant in the Puget Sound region, and in the absence of fire for long periods, the forests may consist largely of this species. However, it was not until the last several thousands of years that it has attained predominance over Douglas fir, probably the result of increased moisture since the warm, dry post-glacial stage (Hansen, 1947). In this study, hemlock is poorly represented in the lower levels, due probably to the sterile soil, unstable physiographic conditions, and the cooler climate of early post-glacial time. Its strongest record occurs in the northernmost section and probably reflects the greater amount of precipitation in the region. It attains a maximum of 56% at 3·2 m. and has been the predominant species during the time represented by the upper two-thirds of the section (Fig. 2). It is most poorly represented in the southern section, where it reaches a maximum of only 16% near the top (Fig. 4). Apparently an annual rainfall of 27 in., little of which falls in the summer, is unfavourable for hemlock. A similar situation is present in the Willamette Valley of western Oregon and on the gravelly outwash plains south of Puget Sound, where a low summer rainfall and/or a gravelly terrain has prevented hemlock expansion to the status of an important climax dominant, such as has occurred in the moister areas of the Puget Lowland. In the Qualicum Beach section, hemlock does not attain significant proportions until the upper six levels, with a maximum of 38% at 1 m. In all sections some of the hemlock pollen undoubtedly drifted down from higher altitudes where hemlock is more abundant.

The fir pollen probably represents all three species of fir on Vancouver Island, with that of lowland white fir being most prevalent. No attempt was made to separate the fir pollen, but the occurrence of some fir pollen grains with large bladders denotes the presence of alpine fir at higher altitudes. Theoretically, the fir pollen in the lower horizons should consist of higher proportions of alpine and silver fir than lowland white fir, because of the probable cooler early post-glacial climate. The only significance that can be attached to the fir pollen profiles is that the higher proportions in the northernmost section are consistent

with the moister climate of the present and the past than farther south on Vancouver Island.

Sitka spruce is poorly represented in all sections, but its strongest and most consistent record is in the bog near Victoria, which is paradoxical in view of the drier climate.

Oregon white oak likewise is sparsely recorded in all sections. Its best record is in the Victoria section where its pollen is present in most horizons upward from the 7 m. level. This is in keeping with its present distribution, and its greatest proportions reflect the drier climate at the south-eastern part of Vancouver Island than that farther north.

Other species and groups recorded by their pollen include Oregon alder, big-leaf maple, birch, *Populus*, mountain hemlock, grasses, composites, Ericaceae, cat tail, sedges, willow (*Salix* spp.) and water lily.

Climatic interpretations

Although the pollen profiles of the three sections reflect the different climates in the three areas, both present and during the post-glacial, there seem to be few or no trends that denote climatic fluctuations. The recorded changes in forest composition probably represent normal forest succession in response to a general amelioration of the climate and modification of the sterile mineral substratum left in the wake of glaciation. These changes were undoubtedly somewhat conditioned by periodic fire and perhaps insect and fungus disease. The warm, dry period which has been dated as between 8000 and 4000 years ago, and is well recorded in pollen profiles from eastern Oregon and Washington and the Willamette Valley in western Oregon, is not in evidence (Hansen, 1947). Although this xerothermic stage is not clearly borne out by pollen profiles of bogs from the Puget Lowland, the consistence of the profiles in showing Douglas fir as attaining its maximum below a volcanic ash level, dated at 6000 years, and the expansion of western hemlock above the ash horizon, suggests a cooler and moister period in more recent time. In the Qualicum Beach section hemlock expands in the upper third, and in the Black Creek section hemlock has been the predominant species during the time represented by the upper two-thirds. The higher proportions of hemlock in the forests in more recent time may reflect slightly increased moisture, but the general increase of this species throughout most of the profiles also suggests development of a soil profile with sufficient humus which is so essential for this species to thrive. The small size of Vancouver Island, the several life zones and prevailing westerly winds have resulted in dilution of the pollen from forests adjacent to the bogs by that from inland forests at higher altitudes. It seems doubtful that the marine climate has fluctuated materially since the early post-glacial amelioration of the pro-glacial influence.

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