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POSTGLACIAL FORESTS IN SOUTH CENTRAL AND CENTRAL BRITISH COLUMBIA

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ABSTRACT. Pollen analysis of 25 peat sections, from the interior of south central British Columbia and central British Columbia and along the Hart Highway, reveals a significant chronological correlation with the thermal maximum as recorded in postglacial sedimentary columns from south central Oregon and eastern Washington. The presence of a volcanic ash stratum in the sections of south central British Columbia at a stratigraphic position enclosed by the xerothermic interval as recorded in the pollen profiles is consistent with the same relationships in the Washington columns. The age of the ash in the Washington sections was originally dated at 6000 years. The radiocarbon date of about 6500 years for the eruption of Mount Mazama in southern Oregon, and the similar relationship of the pumice from this eruption as shown by its stratigraphic position in peat sections to the recorded xerothermic interval suggest that these volcanic eruptions were not far apart in time. The thermal maximum in south central British Columbia is depicted by an expansion of ponderosa pine and grasses, chenopods, and composites sometime after organic sedimentation was initiated and well before the present. The postglacial thermal maximum may have occurred about 6000 years ago, with the xerothermic interval lasting from 7500 to 3500 years ago.

During the summer of 1947 a transect of 14 peat sections was obtained from as many sites of organic sedimentation in the intermountain region of south central British Columbia, along the Cariboo Highway northward to Prince George, and west along the main highway to Hazelton on the Skeena River (fig. 1). Twelve additional sedimentary columns were obtained during the summer of 1952 along the Hart Highway, connecting Prince George and Dawson Creek, the southern terminus of the Alaska Highway, a distance of about 265 miles. All the sections obtained in 1947 and one obtained in 1952, that closest to Prince George, lie within the Fraser River drainage. The other 11 along the Hart Highway lie within the Peace River drainage, of which six are in the Parsnip River basin which drains northward into the Peace River, three lie in the Pine River valley on the east slope of the Rocky Mountains, and two, nearest to Dawson Creek, lie in the Kiskatinaw River drainage.

Pollen analyses of sedimentary columns from these bogs reveal an interesting and significant postglacial forest sequence in the adjacent areas within range of pollen dispersal. The transect cuts across several distinct phytogeographic provinces as well as the range limits of several important arboreal indicator species. Postglacial expansions and contractions of these species as recorded in the pollen profiles reflect climatic trends during the time represented.

The southernmost section was obtained from a large sedge meadow between the towns of Merritt and Princeton, about 20 miles north of the latter (fig. 1). The northwesternmost was taken from a vast muskeg-type floodplain

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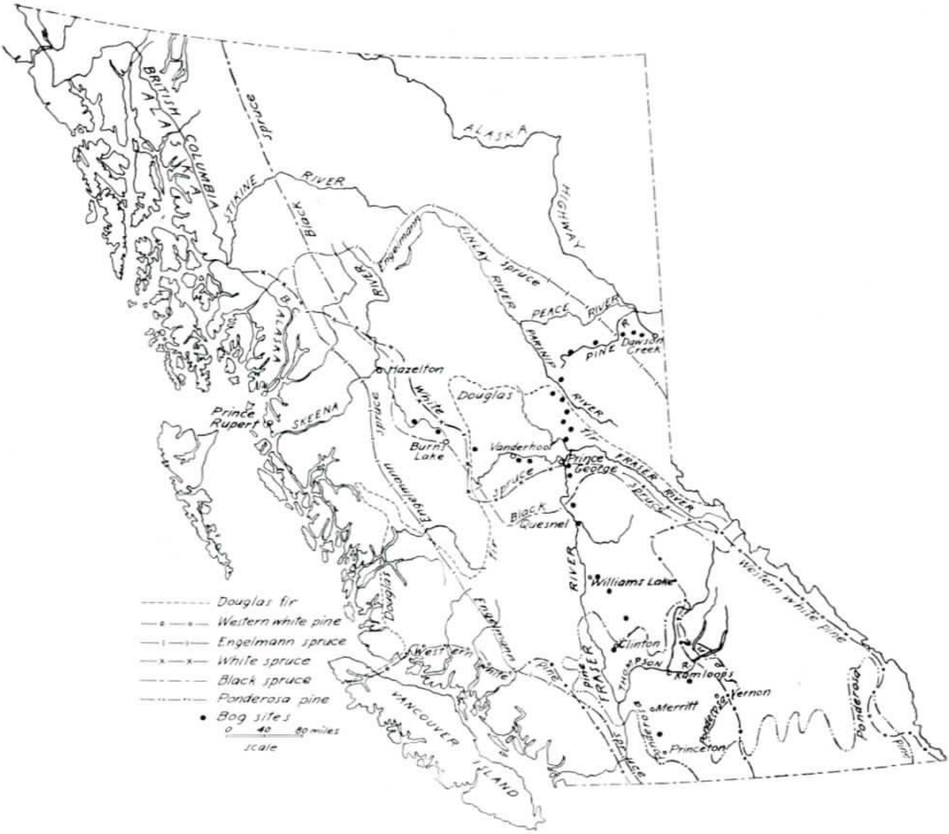

Fig. 1. A somewhat generalized map of British Columbia showing the sites of bogs and approximate ranges of forest trees that are represented by pollen in the sedimentary columns. Range limits of trees are taken from Whitford and Craig, 1918.

bog a few miles east of Houston and about 80 miles southeast of Hazelton. The northeasternmost sedimentary column was taken from a muskeg 19 miles west of Dawson Creek. Coincidentally, each of the two northernmost bogs lie about 450 miles in a straight line from the southernmost and about 250 miles from each other.

The thicknesses of the sections vary from 1.0 to 7.5 meters. This includes varying thicknesses of clay or silty sediments underlying the peat which may or may not contain pollen grains. A section taken from a vast sedge marsh between the towns of Vernon and Kamloops extends down to bedrock, but in boring most sections sand or gravel was reached. All but six of the bogs were developed in basins occupied by lakes as evidenced by an abundance of aquatic plant pollen in the lower levels. The other six, including those in the Fraser River drainage located 5 and 15 miles southeast of Prince George, and those located 19, 40, 71, and 90 miles respectively west of Dawson Creek, were developed on more or less flat terrain and are similar to the muskeg type found farther north, which are often underlain with permafrost or a frost residuum, depending upon their latitude (Hansen, 1950; 1953). A frost residuum was encountered only in a muskeg located 19 miles west of Dawson Creek and this in August. Topographic evidence that these six muskegs were not initiated in standing water is supported by the absence of aquatic plant pollen in the lower levels and by the presence of ericaceous pollen and Sphagnum moss spores in the sediments immediately overlying the blue clay at the bottom of the section. Six sections, four from the Fraser River valley and two along the Hart Highway, were obtained from sedge bogs on which the predominant vegetation consists of sedges, rushes, and cattails, and other species common to wet meadows or marshes formed on floodplains or in shallow ponds and lakes.

The other bogs support typical bog flora including *Sphagnum* spp., several species of ericads, bog birch (*Betula glandulosa*), *Rubus chamaemorus, Empetrum nigrum, Eriophorum* spp., and black spruce (*Picea mariana*). Only two of the bogs in the Fraser River Valley south of Williams Lake support spruce, which was identified as Engelmann spruce (*P. engelmanni*). These are located south of the range of white and black spruce in interior British Columbia. In this drier area Engelmann spruce has apparently found a favorable habitat on the bogs, as it is absent from adjacent higher slopes. In fact, the open slopes adjacent to the bog two miles south of Clinton support both juniper (*Juniperus scopulorum*) and sage (*Artemisia tridentata*). Tamarack (*Larix laricina*) occurs on the five muskegs lying on the east slope of the Rockies. This species is a member of the boreal forest that extends north and west from New Foundland into the Yukon Territory.

In the preparation of the sediments for microscopic study, the potassium hydrate method was used, with gentian violet as the staining medium and glycerin jelly for mounting. From 100 to 200 tree pollen grains were identified from each level. Insufficient pollen was recovered from a section 40 miles west of Dawson Creek for a diagram, but the proportions for the several species were consistent with adjacent sections. It was soon apparent that at least two species of pine pollen were present, and use of the size range method resulted in the separation of those that lie within the size ranges of lodge pole pine (*Pinus contorta*), western white pine (*P. monticola*), and ponderosa pine (*P. ponderosa*) as determined by the author (Hansen, 1947). At least three, and possibly five, of the sites of sedimentation lie within the present range of ponderosa pine. Although the relative size ranges of black and white spruce (*Picea glauca*) pollen indicate that they may be separated (Potzger, 1953), no attempt was made to do this. In the region of this study, the 20 northernmost bogs lie within the ranges of white and black spruce, and all of them within the range of Engelmann spruce (fig. 1). The proportions of spruce pollen in most of the sections are not great, and it seems doubtful if separation of the three species would prove to be of any significance.

Volcanic ash occurs in 13 of the sections. In the 4 southernmost sections the ash is present in a fairly well-defined layer, while in all others except the two nearest Dawson Creek, the glass fragments are scattered in the peat matrix. It is probable that ash is present in all the sections, but samples taken at 2-decimeter intervals evidently omitted the stratum of peat with the scattered glass. Unless a well-defined layer is present, it is not possible to find the glass fragments until microscopic examination is made. This is especially true in limnic peat, where the sediments often are light colored like the ash. The origin of this volcanic material is problematical because of the widespread occurrence of volcanic ejecta in postglacial sedimentary columns in the Pacific Northwest, western Canada, and Alaska. It seems probable that the ash in south central British Columbia is from the same source as a well-defined layer consistently occurring in Washington peat sections (Hansen, 1947). In 10 sections taken in the northern half of eastern Washington this ash stratum occurs at a stratigraphic position at which the pollen spectrum records the postglacial thermal maximum, which is also true in some of the sections of this study. The source of the volcanic glass is probably Glacier Peak in north central Washington, whence it has been traced eastward on Late Wisconsin drift (Waters, 1939). The ash in the sediments becomes thicker to the east and north suggesting that strong southwest winds were in force at the time of the eruption and that the finer components were most abundant. The distance from Glacier Peak to the southernmost site of this study, between Merritt and Princeton, is about 120 miles, which is less than from the peak to bogs in northeastern Washington where the ash is several inches thick. The presence of only one ash horizon in the postglacial sediments of this region and its position close to the thermal maximum as denoted by the pollen profiles makes it reasonable to assume that it is from the same source. One or more ash horizons were noted in many sections along the Alaska Highway in northeastern British Columbia, the Yukon Territory, and Alaska (Hansen, 1950; 1953). Most of these are near the surface suggesting recent deposition. The volcanic glass near the top in the two sections near Dawson Creek may have had the same source as those along the Alaska Highway (fig. 8-A, D).

VEGETATION OF THE REGION

The vegetation of the region within range of pollen dispersal to the sites of the sediments varies greatly. The region south of Quesnel, from about the 53rd parallel southward to the boundary of the United States and between the Coast Range and the Rocky Mountains is covered with grasslands, savanna, and open forest because of the dryer climate caused by the rain shadow cast by the Coast Range. Before the advent of white man and agricultural development, it is estimated that over 3,000,000 acres were occupied by grassland (Tisdale, 1947). These grasslands occur in the larger and lower valleys and adjacent slopes to an altitude of 3000 to 4000 feet depending upon slope and exposure. The open forest interfingers into the grasslands where moisture and exposure afford more mesic conditions. The annual precipitation in the dryer, southern interior ranges from about 7 inches at Ashcroft to over 16 inches at Quesnel at the northern limit of the grassland region. In the lower and dryer areas of the grassland such xeric indicators as *Artemisia tridentata*, *A. frigida*, *Purshia tridentata*, and *Chrysothamnus nauseosus* are present. On alkaline areas *Sarcobatus vermiculatus*, *Salola kali tenuifolia*, *Chenopodium album*, *C. fremontii*, *C. humile*, *Atriplex argentea*, and *Salicornia europea* occur. The most common native grasses of the southern interior of British

Columbia are *Agropyron spicatum, Poa secunda, Festuca idahoensis, F. scabrella, Stipa commata, S. columbiana, Koeleria cristata,* and *Sporobolus cryptandrus.* The introduced species, *Bromus tectorum*, is also common in areas that have been overgrazed and repeatedly burned. Six of the sections are located within the grassland region, and the importance and significance of the grasses, forbs, and shrubs of this xeric area are reflected in their pollen profiles. The proximity of the open forests on the higher adjacent slopes and the denser more mesic forests on the upper slopes, both to the east and west, however, is reflected in the sedimentary columns due to the greater amount of windborne pollen derived from the arboreal species. The relative expansion and contraction of grassland and forest attributed to climatic fluctuation are reflected in the profiles of the several sections.

As stated before, the transect of sections traverses the range limits of certain arboreal climatic indicators. The most important of these is ponderosa pine, whose northernmost limits occur a few miles north of Clinton in the vicinity of Chasm (fig. 1; Whitford and Craig, 1918). Western white pine likewise is restricted to the southern part of interior British Columbia, but its range extends northward somewhat farther on the west slope of the Coast Range and in the Rockies to the east, occupying the higher slopes where there is sufficient moisture. Whitebark pine (*Pinus albicaulis*) also occurs on the dryer upper slopes, largely within the range of white pine but much more sparsely. Lodgepole pine, predominantly represented in the sedimentary columns, is the most common and widespread conifer in the region. It is the most xeric forest tree species next to ponderosa pine, also thrives on poor soil, and invades at the expense of others where fire has occurred. It becomes sparse on the higher slopes of the Coast Range where there is more moisture and northward where it suffers more competition from spruce and aspen (*Populus tremuloides*).

The range of Douglas fir (*Pseudotsuga taxifolia*), recently changed to *P. menziesii*, which is represented in most of the sections, encloses the sites of all the sediments except the six on the eastern slope of the Rockies. It is most abundant in the southern and eastern part and thins out northward to an occasional tree where local conditions are favorable. The only species of fir whose range is coextensive with all the sites of sedimentation is alpine fir (*Abies lasiocarpa*). Lowland white fir (*A. grandis*) occurs only in south central British Columbia but extends farther northward on the lower west slopes of the Coast Range. An occasional specimen was noted in the vicinity of the Merritt section. Silver fir (*Abies amabilis*) is absent in interior British Columbia, but is abundant on the west slopes of the Coast Range and extends northward to southeastern Alaska. Noble fir (*A. procera*) is present only in southwestern British Columbia.

Four species of spruce occur in British Columbia. In this study Sitka spruce (*Picea sitchensis*) is unimportant because it is confined to the southwestern part of the province and ranges northward along the coast into Alaska to Cook Inlet. It is possible that this species is represented in the Merritt section since it occurs within 25 miles to the west. The only spruce whose range encloses all the sites of this study is Engelmann (*P. engelmanni*) which occurs on the east slope of the Coast Range northward through Hazelton almost to 58° latitude, and then ranges eastward and southeastward through the Rocky Mountains. Black spruce ranges south to Quesnel while white spruce extends somewhat south of Prince George in the interior (fig. 1). The twenty northernmost sections lie within the ranges of black and white spruce. Extensive pure stands of white spruce occur along the Hart Highway in the mountains.

The range of western hemlock (*Tsuga heterophylla*) which is sparsely and sporadically represented in most of the interior sections occurs in the Coast Range to the west and on the west slope of the Rockies. A few specimens were noted within 50 miles of the northwesternmost section. Mountain hemlock (*T. mertensiana*) which is represented more sparsely than western hemlock has somewhat the same range as the latter but at higher elevations. Western red cedar (*Thuja plicata*) has a range similar to that of western hemlock, but it extends across the southern part of the province to connect the eastern and western belts. Western larch (*Larix occidentalis*) is restricted to the southeastern part of the province where it is more or less coextensive with ponderosa pine but at higher elevations. As stated previously, tamarack (*L. laricina*) is a member of the boreal forest which extends across the continent. It is confined to bogs and muskegs except at the northern limits of its range where it occurs on higher ground. Pollen of *Larix* apparently is not well preserved in peat, and thus its record is absent. It is evident that only three species of conifers, lodgepole pine, alpine fir, and Engelmann spruce have ranges which in general are coextensive with all the sites of sedimentation of this study.

The two most important and widespread broadleaf arboreal species are aspen (*Populus tremuloides*) and northern black cottonwood (*P. trichocarpa hastata*). Aspen thrives as a result of fire, and it will largely replace lodgepole pine if the pyric influence is strong and often repeated. The black cottonwood occurs mostly on floodplains in the southern part of its range, but it becomes an upland species under moister conditions northward. Extensive stands were noted along the Hart Highway on the east slope of the Rockies. White alder (*Alnus rhombifolia*) ranges into south central British Columbia where it occurs chiefly along stream courses, and its pollen occurs in the peat sections from this area. None of the sites of sedimentation lies within the range of red alder (*A. oregona*) which is confined largely to the coast and coast mountains, extending northward into Alaska. It was noted in the Hazelton region, which is probably about as near as it occurs to any of the bogs of this study. The range of western birch (*Betula occidentalis*) and its varieties is not well known in British Columbia. It was noted as being locally abundant along the Fraser River south of Prince George and in the vicinity of Hazelton. It was not abundant along the Hart Highway, although on the east slope of the Rockies white birch was locally present. It is probable, however, that the birch noted here was *Betula papyrifera* or one of its varieties. Birch is only sparsely represented in the sedimentary columns and its pollen is probably mostly that of bog birch (*B. glandulosa*).

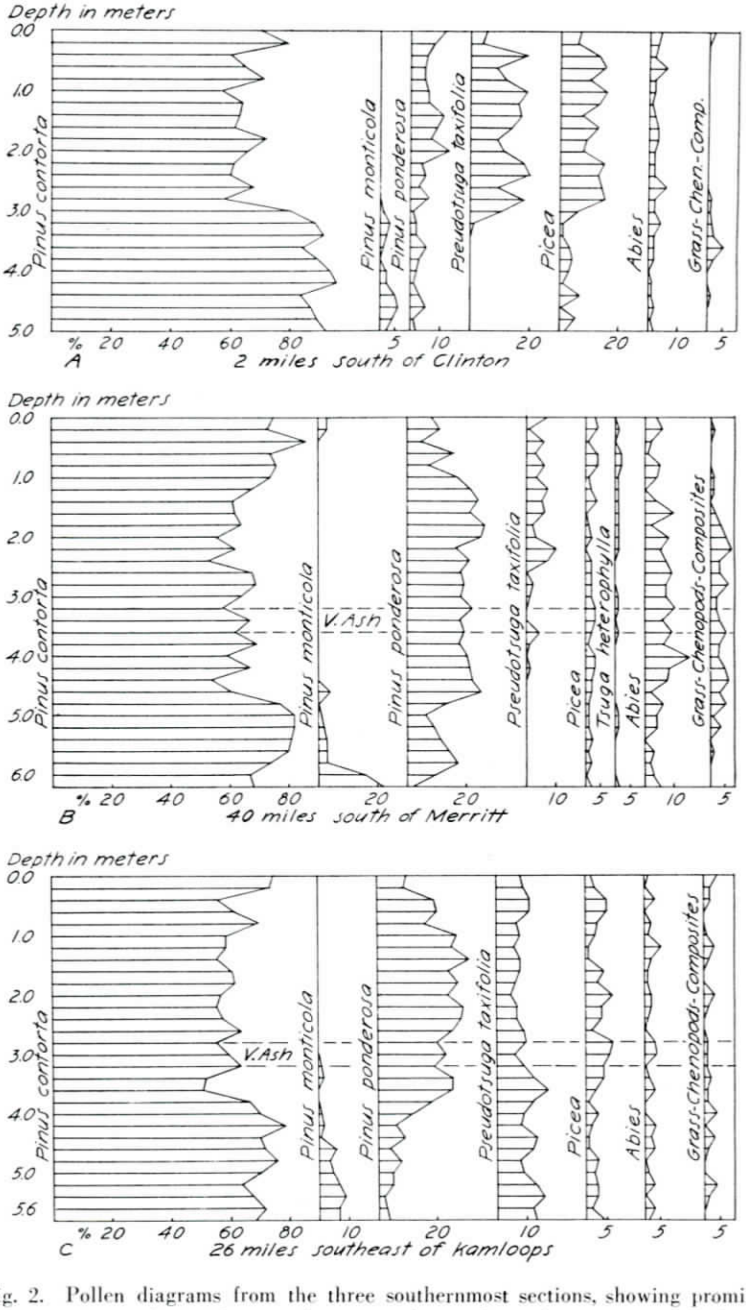

Fig. 2. Pollen diagrams from the three southernmost sections, showing prominence of ponderosa pine and significance of grasses, chenopods, and composites in relation to the volcanic ash horizon, which probably marks the time of the thermal maximum in south central British Columbia.

POSTGLACIAL VEGETATION

Lodgepole pine is the most abundant species in all the 25 sections, being recorded to well over 50 percent at most levels (figs. 2-8). In fact, at very few horizons is it superseded by other species, and it has an average of over 60 percent throughout and about 83 percent at the lowest level. The most consistent trend of lodgepole is a general decline upward in the profiles to a point somewhere in the middle third of the sections. This occurs in 17 of the 25 sections. From this minimum, the trend is a general increase to or near the uppermost horizon. Most of the sections reveal an increase in the top level, which is probably to be associated with the advent of white man and the attendant modification of the environment through burning and deforestation which has been favorable for lodgepole. Although lodgepole is predominantly represented in the lower levels of most postglacial sedimentary columns in the Pacific Northwest, it was rapidly replaced by longer-lived and more shade-tolerant species as the physiographic conditions in the wake of retreating ice were stabilized and the mineral soil modified (Hansen, 1947). In the Puget Lowland of western Washington, Douglas fir was able to crowd out the smaller and shorter-lived lodgepole, and hemlock also increased, especially after the postglacial thermal maximum. In eastern Washington lodgepole was not initially so abundant as farther west but declined more slowly and has remained more abundant than west of the Cascades. Grasses, chenopods, and composites partially replaced lodgepole as the climate became warmer and dryer and in turn were replaced by ponderosa pine as cooler and moister conditions prevailed. In south central and west central Alberta lodgepole pine was generally predominant during postglacial time (Hansen, 1949; 1949a). Here its chief competitor was spruce, which apparently was able to supersede it for brief periods. The present abundance of aspen suggests that it played an important role in succession after fire, though poor preservation of aspen pollen in peat largely conceals its history. Farther north in Alberta, spruce and lodgepole have competed equally, and still farther north along the Alaska Highway in northeast British Columbia spruce has been more abundant (Hansen, 1950; 1952). Likewise along the Alaska Highway in the Yukon Territory, lodgepole and spruce competed for predominance, with the former somewhat favored in sections as far as milepost 931 about 15 miles beyond Whitehorse (Hansen, 1953). Lodgepole then becomes sparsely represented in sections along the Alaska Highway to the Alaska border, while in interior Alaska, pine pollen occurs only sporadically. Pollen profiles from southeastern Alaska show that lodgepole was predominant in the lower levels in some sections and in the upper horizons in others, while still others show that it was superseded throughout by Sitka spruce and western hemlock (Heusser, 1952). The initial postglacial invasion of lodgepole is assumed to have been on deglaciated terrain while its expansion in more recent time is attributed to its development on the muskegs. In the region of this study, however, the record of lodgepole represents its upland succession and it would seem that conditions have been favorable for this species during the entire postglacial. Both soil and climate, as well as fire, have favored it over its competitors, as none of the climax species in either the southern or northern sectors has been able to supersede it to any appreciable extent during the time represented by the sediments.

A significant proportion of pine pollen in the lower levels of five of the southern sections was identified as that of western white pine by the size range method (figs. 2, 3). Although error is possible with this method, the occurrence of western white pine in this area in early postglacial time is consistent with

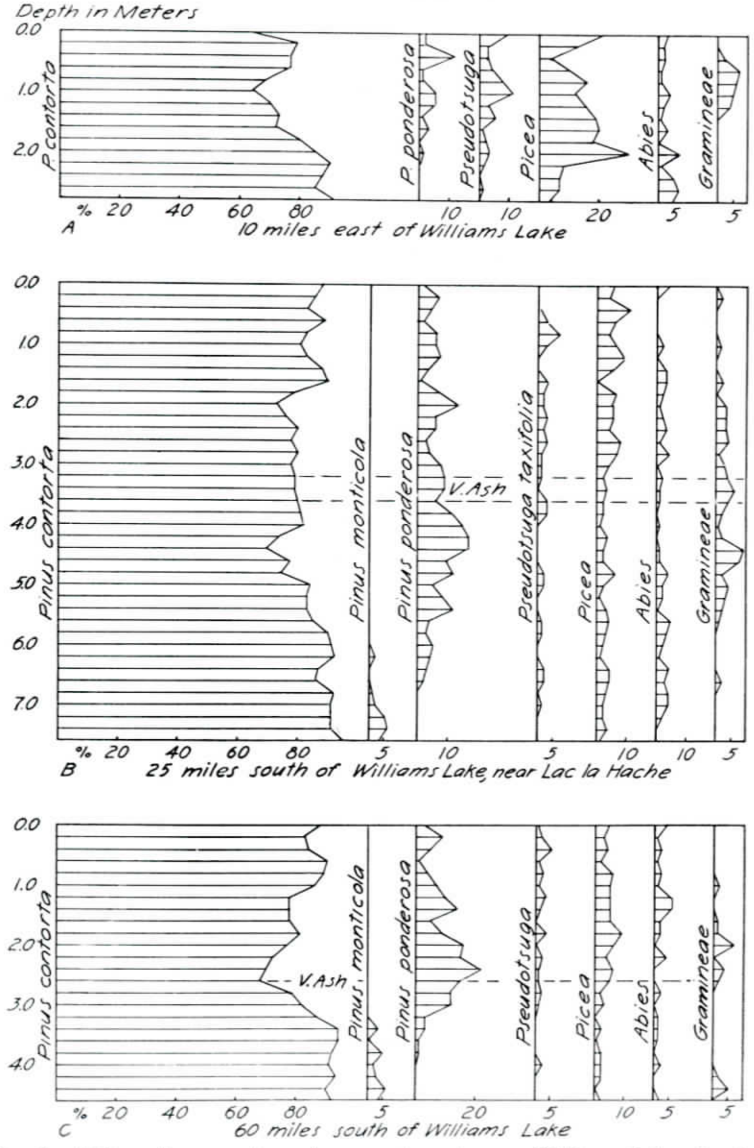

Fig. 3. Pollen diagrams from bogs south and near Williams Lake showing the ponderosa pine and grass maxima near the volcanic ash horizon. Decline of white pine and Douglas fir reflects their decreasing abundance northward in the region.

its present range and the fact that this species thrives in a moister climate such as must have existed for some time after the ice receded. In most Washington peat sections, white pine reveals its strongest record in the lower levels although it is present in low proportions throughout (Hansen, 1947). Its apparent absence in sections farther north suggests that it was unable to invade

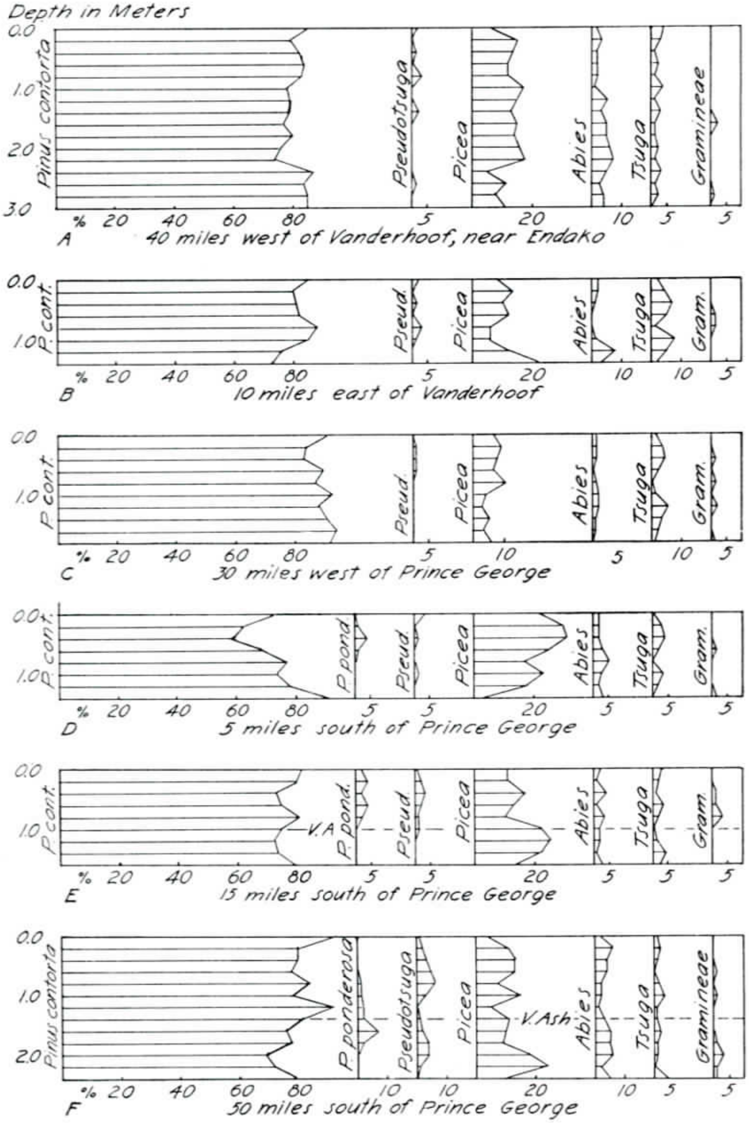

Fig. 4. Pollen diagrams of six shallow sections south and west of Prince George showing predominance of lodgepole pine throughout and absence of ponderosa pine west of Prince George. The presence of hemlock reflects the moister climate toward the coast and at higher elevations.

the dryer interior during early postglacial time, even under the moister and cooler conditions that must have prevailed.

Perhaps the most significant pollen record in the southern sector of this study as far as postglacial climate is concerned is that of ponderosa pine. The strongest record occurs in the five southernmost sections, all of which lie within the present range of this species (figs. 2, 3). It is also sparsely recorded in the next four sections northward, the last being about 5 miles from Prince George, beyond the known present day range of ponderosa pine (fig. 4-D). While it is possible that the range of ponderosa pine is more extensive in interior British Columbia than is known, its pollen record gives evidence that it was more widespread and abundant during the postglacial xerothermic interval. This is supported by the fact that its higher proportions in general occur in the middle third of the profiles with a general decline in the upper levels, indicating that postglacial warming and drying reached a maximum at some time in the past, followed by cooler and moister conditions. If the stratum of volcanic ash cutting through the ponderosa pine maximum in three of the sections is the same as that present in many Washington sedimentary columns, it further supports the evidence that expansion of ponderosa pine

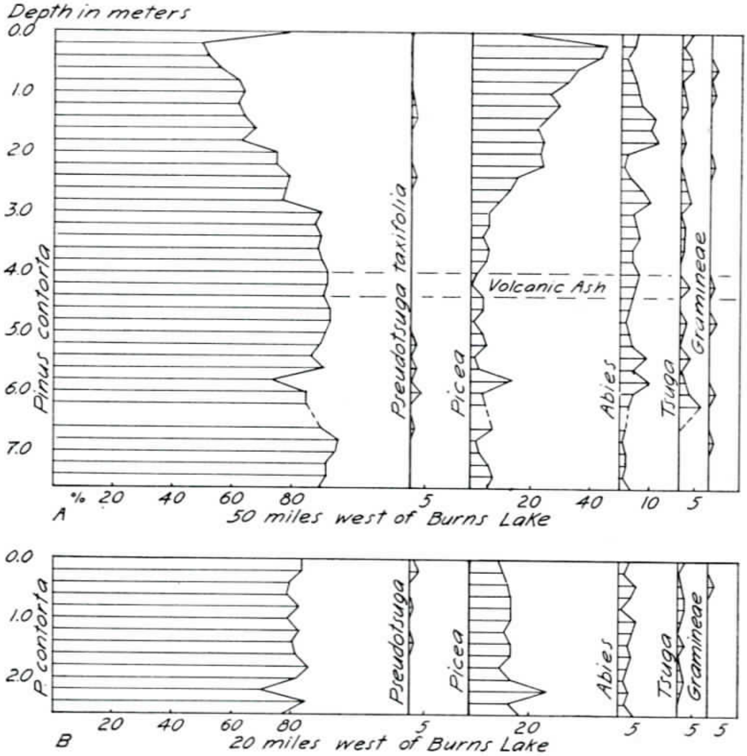

Fig. 5. Pollen diagrams west of Burns Lake, showing predominance of lodgepole pine, absence of ponderosa pine and only trace of Douglas fir. Volcanic ash may be from Glacier Peak in north central Washington.

in this area occurred in response to the xerothermic interval. In the Washington sections, the ash occurs at or near the maximum of grasses, chenopods, and composites, which is interpreted as expressing the thermal maximum in this region.

The record of grasses, chenopods, and composites is parallel to that of ponderosa pine in that their greatest proportions occur in the middle third of most of the sections (figs. 2, 3, 4, 5). In the three southernmost sections the three groups are represented, while only grass pollen was noted in those to the north. Along the Hart Highway in only two, those nearest to Dawson Creek, was grass pollen noted, although the occurrence of an occasional grass pollen is hardly sufficient to use as a basis for postulating climatic trends (fig. 8-C, D). It seems probable, however, that grasses are considerably underrepresented in sections from bogs in the grassland area, because in the upper horizons they are not recorded or only to a few percent. This is well borne out by postglacial pollen profiles in the grasslands of eastern Washington and Oregon, where in certain sections located many miles from present-day forests, tree pollen is predominant over that of grass in the upper levels (Hansen, 1947). In 17 peat sections along the Alaska Highway in British Columbia, grass is recorded only sparsely and sporadically, even in the Peace River region where soil profiles indicate a prairie flora of long standing. In south central Yukon, however, grass is well represented in four sections northwestward as far as milepost 666, and then becomes only sparsely and sporadically represented in sections as far as milepost 724 (Hansen, 1953). Paradoxically, however, it is not well represented in sections from the parkland area west of Whitehorse, where grass is abundant today. Likewise, in the Grande Prairie-Lesser Slave Lake region of Alberta, grass is poorly represented although the present parkland and prairie soil profiles indicate that grass has been abundant in the past. In peat sections in the vicinity of Edmonton, Alberta, grasses, chenopods, and composites are well represented, and at a stratigraphic position which corroborates other evidence for the existence of a postglacial thermal maximum (Hansen, 1949; 1949a).

Douglas fir is represented in all but the seven peat sections, nearest to Dawson Creek (figs. 2-8). It reveals its strongest record in the three southernmost sections and becomes weaker to the north and west. Its most consistent record is in the Vernon-Kamloops section, while it attains its highest proportions in the section near Clinton, where it supersedes both spruce and ponderosa pine at several horizons. No significant trends occur in the profiles of Douglas fir and no correlations with those of other species represented are evident that would depict a reciprocal relation influenced by climatic trends or other factors controlling forest succession. In the grassland sector of British Columbia, apparently the climate was never sufficiently moist to encourage its expansion, although its belated appearance in the Merritt and Clinton sections may have been a response to a moister climate since the postglacial thermal maximum (fig. 2). Douglas fir has not been postglacially abundant east of the Cascades in Oregon and Washington. In north central Washington and northern Idaho it has played an important role in the postglacial forests, but not to the extent it has in the Puget Lowland. In the former region its

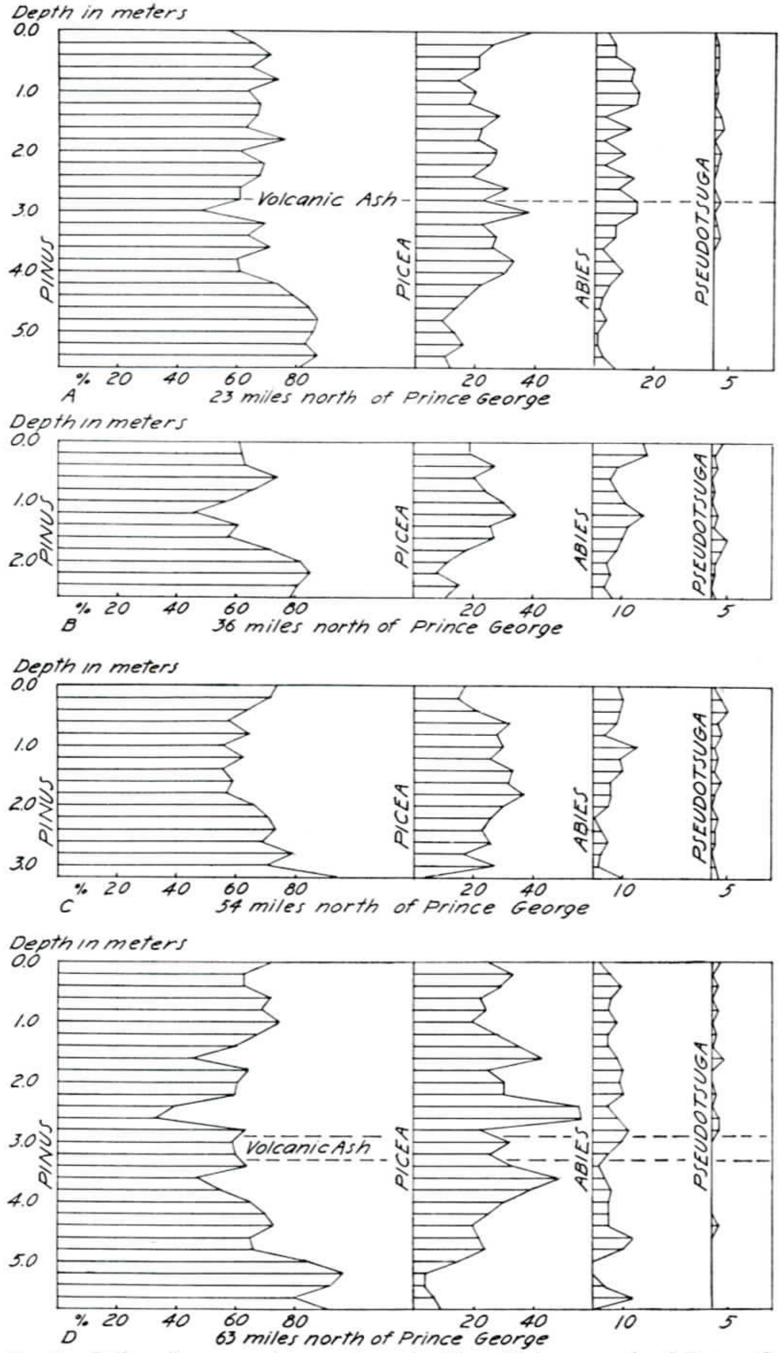

Fig. 6. Pollen diagrams of bogs along the Hart Highway north of Prince George showing predominance of lodgepole pine, and increasing importance of spruce under the moister and cooler climate. Douglas fir pollen was probably carried in from the south and west.

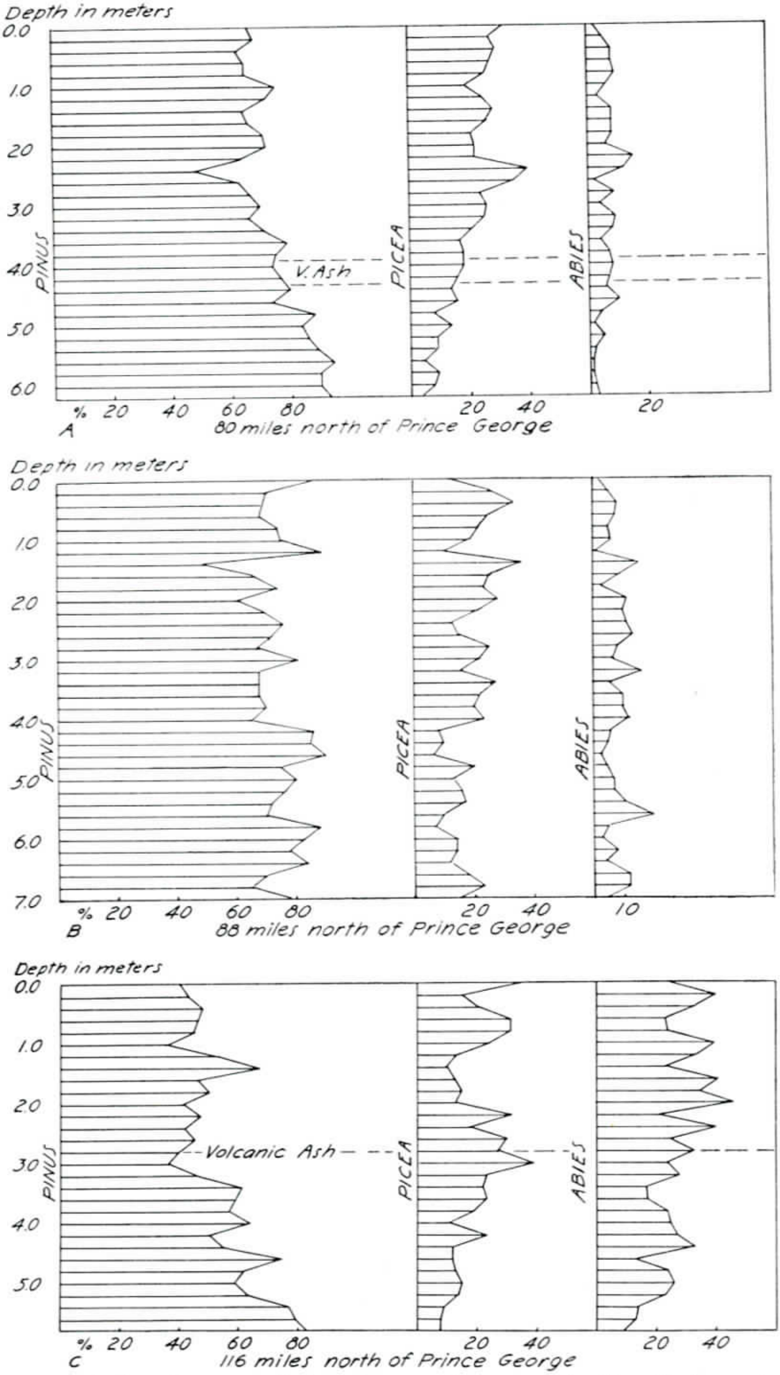

Fig. 7. Pollen diagrams of three deep sections along the Hart Highway showing predominance of lodgepole pine on gravelly mineral soil. C shows the highest proportions of fir in all sections, reflecting the montane position of the sites of the sediments.

phytosociological relationships have been with other species than in the Puget Sound region. It is only sporadically recorded in peat sections on the eastern slope of the Rockies in Alberta (Hansen, 1949).

Interpretation of spruce pollen profiles is complicated by the probable presence of three species in many of the sedimentary columns. Engelmann spruce may possibly be represented in all sections because all sites of sedimentation lie within its present range. In the two southernmost sections spruce is sparingly represented, although no spruce occurs on the bogs (fig. 2). In the Clinton section, the site of which supports Engelmann spruce, spruce pollen is absent in the lower third, and then abruptly appears, suggesting its invasion of the bog surface as conditions became favorable. In the other three sections from south of the ranges of white and black spruce, only that near Williams Lake shows spruce well represented (fig. 3-A). Here the bog surface supports a well-developed stand of spruce. In general, the proportions of spruce pollen become greater northward in the transect of sedimentary columns (figs. 4-8). Most sites of sedimentation north of Quesnel support black spruce and the pollen proportions include this species as well as the upland white and Engel-

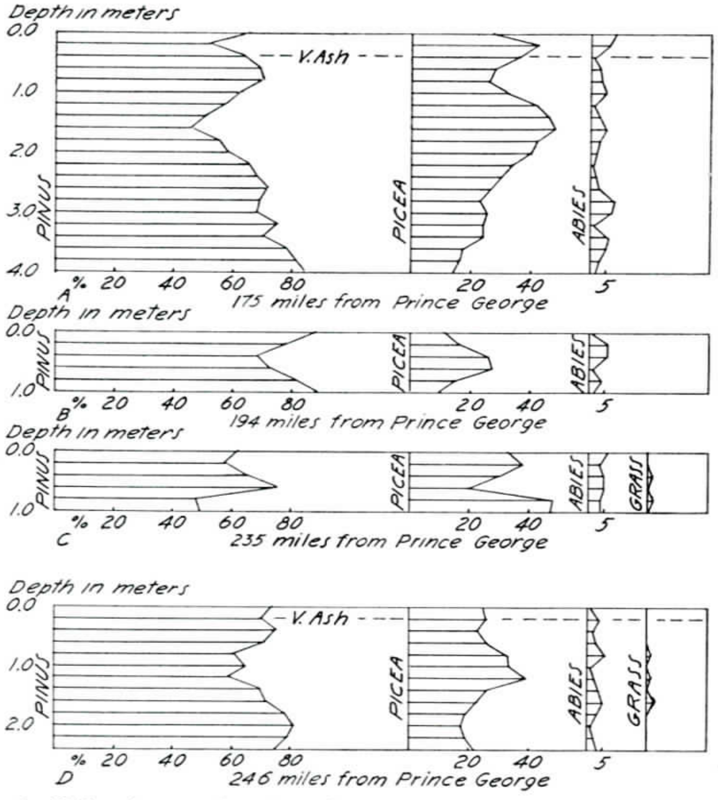

Fig. 8. Pollen diagrams from bogs along the Hart Highway, on the east slope of the Rocky Mountains, west of Dawson Creek. Increase of spruce at the expense of fir may reflect the presence of the former on the muskegs and the lower elevation. Volcanic glass is probably from the northwest rather than Glacier Peak to the south.

mann spruce. The strongest representation of spruce is along the Hart Highway where it attains proportions of over 40 percent and is consistently recorded to 20 percent or more (figs. 6-8). The fluctuations of spruce are largely converse to those of lodgepole, which suggests the possibility that one species may have increased in abundance while the other remained stable, and yet is recorded as having declined. For this reason, the level-to-level fluctuations cannot be considered as too significant in interpreting successional trends. Many of the spruce profiles reveal a maximum in the middle third which is not consistent with the maximum of ponderosa pine in the southern sections, because the latter has been interpreted as an expression of the thermal maximum. It seems probable, however, that the complementary fluctuations of spruce and pine reflect the influence of fire. Recurring fire is favorable for lodgepole because of seed retention in the cones until the heat of a fire causes them to open, shedding many years of seed. The early pollen-bearing characteristic of lodgepole causes it to be strongly represented in peat in comparatively a few years after a holocaustic fire. In the absence of fire spruce, as a climax species, was able to expand until another series of fires.

It is possible that spruce pollen in the lower horizons, especially in the southern sections is that of white spruce, as it must have migrated northward from its proglacial sites after the recession of the ice. It is possible also, that spruce postglacially reinvaded central and northern British Columbia from the north and east, as there is evidence that ice-free, forested areas persisted along the eastern flank of the Rocky Mountains in Alberta and British Columbia during the Late Wisconsin glaciation as well as in west central Yukon (Hansen, 1950; 1953; Hultén, 1937). In 16 sections studied, spruce declines in the upper level or two while pine increases. This same relationship between spruce and pine exists in 51 other sections in Alberta, British Columbia, and the Yukon Territory (Hansen, 1949; 1949a; 1950; 1952; 1953). This regional systematic and consistent pattern suggests the influence of white man and/or the dryer and warmer climate of the past 200 years (Lawrence, 1950). The evidence that lodgepole pine rather than spruce, was the predominant postglacial arboreal invader, emphasizes its great ecologic amplitude and its maneuverability under the physiographic instability in the wake of the retreating ice. As stated above, this is well substantiated by its postglacial record in the postglacial sedimentary columns of the Pacific Northwest, western Canada, and Alaska.

Fir (*Abies*) is represented at practically every level in all sections, and in general, becomes more strongly recorded northward in the transect of sedimentary columns (figs. 2-8). It is difficult to discern any definite successional trends in the fir pollen profiles in relation to other species or the environmental conditions. In the interior in the Fraser River Valley, fir pollen probably came from the higher slopes where alpine fir occurs rather sparsely. In the southern sector fir is best represented in the section 40 miles south of Merritt (fig. 2-B), where it occurs fairly abundantly on the upper slopes of surrounding mountains. The strongest record of fir is revealed in the sections along the Hart Highway north of Prince George, with the best representation at the site 116 miles north (fig. 7-C). This muskeg is in a montane region in which the adjacent forests are composed of a high percentage of fir. Fir decreases northeastward from this site, and in the four muskegs nearest to Dawson Creek, is recorded to a maximum of only 8 percent (fig. 8-A). In general the record of fir in this study is similar to that in southwestern Yukon, northeastern British Columbia, and north central Alberta, while in west central Alberta it is most strongly represented in the lower levels indicating its existence farther down on the eastern slope of the Rocky Mountains during the cool, moist climate in the early Postglacial (Hansen, 1949; 1949a; 1950; 1952; 1953). It apparently has never played an important role in postglacial forest succession. The pollen record in southeastern Alaska suggests that silver fir (*A. amabilis*) has not migrated northward along the coast to any great extent during the Postglacial (Heusser, 1952).

Both western and mountain hemlock are represented in most of the sections, although the latter so sparsely and sporadically that no profile is shown. Western hemlock occurs sparingly in the Merritt section, but not in the other sections south of Williams Lake (fig. 2-B). It becomes more strongly represented in sections north of Quesnel and northwest of Prince George where it was frequently noted in the forest (figs. 4, 5). An occasional pollen grain of hemlock was noted in sedimentary columns north of Prince George, but on the east slope of the Rockies it apparently is entirely absent.

POSTGLACIAL CLIMATE AND CHRONOLOGY

The sites of all sections lie within the region of Cordilleran glaciation, probably Late Wisconsin (Mankato) in age (Antevs, 1945; Flint, 1947). The arboreal pollen record in most sections begins in the lowest organic sediments and even in the underlying silty deposits suggesting an early invasion of forests after deglaciation. There seems to be no distributional pattern with respect to the relative depths of sedimentary columns. The deeper sections occur in the dryer interior as well as in the moister areas, while the northern deposits are as deep as those in the southern sector. This suggests that the rate of accumulation of the organic sediments has been a response to local conditions rather than regional environments caused by climate and latitude.

The interpretation of the chronology of the recorded forest succession and climate can be only general as it must be based upon correlation with pollen studies elsewhere, position of the volcanic ash layers, the date of the thermal maximum as interpreted in other regions from pollen studies, varved clays, and radiocarbon dates that bear either a direct or indirect relationship to organic deposits and glacial-derived strata. The radiocarbon date of 11,400 years for the pre-Mankato Two Creeks Forest Bed has become an important starting point for the postglacial chronology of trends and events that are recorded by artifacts and sediments (Arnold and Libby, 1950). The figure of 11,000 years is set for the maximum advance of the Mankato stage because the ice actually moved about 25 miles beyond the forest bed in that region. This date and others derived by radiocarbon assay in eastern North America has suggested a round figure of 10,000 years for dating pollen records of peat sections lying on Late Wisconsin drift in eastern North America (Flint and Deevey, 1951). This does not mean, however, that the same date necessarily applies to postglacial peat sections in the Pacific Northwest or western Canada, because much of the former lies south of the glacier terminus, and the fact that the glaciers originated from different centers.

In the Pacific Northwest the radiocarbon date of about 6500 years for the eruption of Mount Mazama, which resulted in the formation of Crater Lake, serves as chronological starting point (Flint and Deevey, 1951). The pollen record of postglacial vegetation in the northern Great Basin of south central Oregon reveals that grasses, chenopods, and composites attained their maximum near the time of the deposition of Mount Mazama pumice (Hansen, 1947). Farther north in eastern Washington, the pollen record of these same groups in 7 peat sections, also strongly portrays a thermal maximum, which is chronologically correlated in the region by the occurrence of a single volcanic ash stratum which has been assigned to Glacier Peak in north central Washington. The ash layer occurs at the level which these groups of plants attain their maximum. Quite some time before the radiocarbon dating method had been devised (Libby and Arnold, 1950), the author estimated the Washington ash at about 6000 years, on the basis that the warm, dry interval had been dated at between 8000 and 4000 years ago (Antevs, 1946; Hansen, 1947). The author also dated the eruption of Mount Mazama at about 10,000 years, as a compromise with his co-workers, although he believed that the pollen records in the northern Great Basin denoted a somewhat lower figure (Hansen, 1947). It would seem that the figure of 6000 years for the Washington ash is not too far off, in relation to the Mt. Mazama date, as both ash and pumice occur at a stratigraphic position at or near the grass-chenopod-composite maximum. If we assume there was no appreciable time lag in the development of the thermal maximum between south central Oregon and eastern Washington, these two periods of volcanic activity may not have been far apart in time.

The stratigraphic position of the Glacier Peak ash in the sections of this study seems to be about the same in relation to the recorded thermal stage as in Washington, although the expansion of grasses, chenopods, and composites is not so strongly marked. This would suggest that in more northern latitudes the xerothermic stage was not so well defined. This is further supported by the recorded increase in ponderosa pine at the expense of the more xeric plants in the upper levels of the Washington sections, reflecting a response of pine to a cooler and moister climate. In British Columbia, however, ponderosa pine has been an indicator of warmer and dryer climate and was replaced in the upper levels by species favored by cooler and moister conditions. Even beyond the present range of ponderosa pine the thermal maximum is slightly reflected although apparently the climate never warmed sufficiently to foster an influx of chenopods and composites (figs. 3, 4).

In southeastern Alaska, Heusser (1953) has interpreted a warm, dry period from pollen profiles as having been in effect between 5000 and 2000 years ago, as based upon a radiocarbon date. No such warming and drying seems to be recorded in the pollen profiles of coastal bogs in Washington and Oregon, however, while it is only slightly indicated in the Puget Lowland (Hansen, 1943; 1944; 1947).

The author has dated the Pacific Northwest sedimentary columns at between 15,000 and 18,000 years, as based upon the thickness and types of peat above and below the volcanic ash level of 6000 years (Hansen, 1947). In this study, what is assumed to be the same ash occurs at about the middle of those sections in which it is present. If the estimated age of 6000 years for the ash is used, it would suggest a total age of 10,000-12,000 years for the sections, assuming that the rate of peat deposition is constant. The rate of deposition of limnic peat, however, which lies below the ash horizon, is slower than that of fibrous peat, above the ash, so that greater age may be possible. These figures imply a somewhat greater age for peat sections in western than in eastern North America. This is not untenable, however, because the Cordilleran ice had a different center of origin than the eastern ice sheets and its proximity to the marine climate of the Pacific coast may have resulted in earlier withdrawal of the ice from this region.

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