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POSTGLACIAL FORESTS ALONG THE ALASKA HIGHWAY IN BRITISH COLUMBIA

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POSTGLACIAL FORESTS ALONG THE ALASKA HIGHWAY IN BRITISH COLUMBIA*

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PEAT sections were obtained from seventeen bogs and muskegs located along the Alaska Highway in British Columbia during August 1947. The area covered extends from Dawson Creek at the southern terminus of the highway to Watson Lake at mile post 634, just over the border in the Yukon Territory (fig. 1). The sections vary in depth from 0.5 to 7.0 meters, and with the exception of one bog which was frozen near the bottom, the sedimentary columns extend down to sand and gravel (table 1). Most of the sections were taken from muskegs, formed in broad, shallow basins without early aquatic stages as shown by the absence of hydrophytic plant pollen in the lower horizons. Only two sections were obtained from swampy bogs exhibiting successional plant zonation with open water in the center (fig. 2*a*). Several sections were taken from bogs formed on flood-plains with sluggish streams coursing through them. The surface of the true muskegs was very dry at this season and no difficulty was experienced in walking through them. The areal extent of the bogs vary from less than an acre to several square miles.

The most common and consistently present plants noted on the bogs were *Picea mariana, Larix laricina, Ledum groenlandicum, Vaccinium oxycoccus, V. uliginosum, Betula glandulosa, Kalmia polifolia, Andromeda polifolia, Chamaedaphne calyculata, Empetrum nigrum, Potentilla palustris, Menyanthes trifoliata, Drosera rotundifolia, Eriophorum* spp., *Carex* spp., *Betula papyrifera, Rubus chamaemorus, Sphagnum* spp., *Cornus canadensis,* and *Mianthemum canadense.* Many other species of plants were collected from the bogs and have been deposited in the Oregon State College herbarium. The presence or absence of various species of plants growing on the bogs and muskegs apparently has been influenced greatly by fire.

Little is known about the glacial geology of northern British Columbia but it is evident that the region was glaciated by pre-Wisconsin ice sheets and probably by both the Early and Late Wisconsin glaciers.[1] The Alaska Highway follows along the eastern flanks of the Rockies as far as Fort Nelson and then swings westward into and through the eastern part of the range into the Laird River valley. Thus the region of this study was probably covered at various times by both the Cordilleran glacier moving eastward down the mountain slopes and the Keewatin ice sheet moving southwestward from its center west of Hudson Bay. Granitic boulders derived from the Canadian

TABLE 1

Number of section	Mile post	Total depth of section in m.	Depth of pollen profiles in m.	Volcanic glass in upper levels
1	28	4.0	3.2	
2	61	1.8	1.6	
3	115	3.0	2.4	
4	148	1.2	1.0	X
5	178	1.5	1.2	X
6	230	1.0	0.8	X
7	253	7.0	6.6	
8	280	1.4	1.0	X
9	341	1.5	0.6	
10	364	1.5	0.9	X
11	381	0.5	0.5	
12	415	0.6	0.6	
13	450	0.5	0.5	X
14	487	0.5	0.5	
15	520	1.0	1.0	X
16	557	3.0	3.0	X
17	580	4.2	4.2	X

* The author is grateful to the American Philosophical Society for a grant from the Penrose Fund to defray the expenses of the field work and equipment, to the John Simon Guggenheim Memorial Foundation for a fellowship during 1947–1948 which permitted him to devote all of his time to research, and to the General Research Council of Oregon State College for a grant for certain laboratory supplies and assistance.

Presented at the annual meeting of the Northwest Scientific Association, Spokane, Washington, January 28, 1949.

[1] Flint, R. F., *Glacial geology and the Pleistocene epoch,* N. Y., Wiley, 1947.

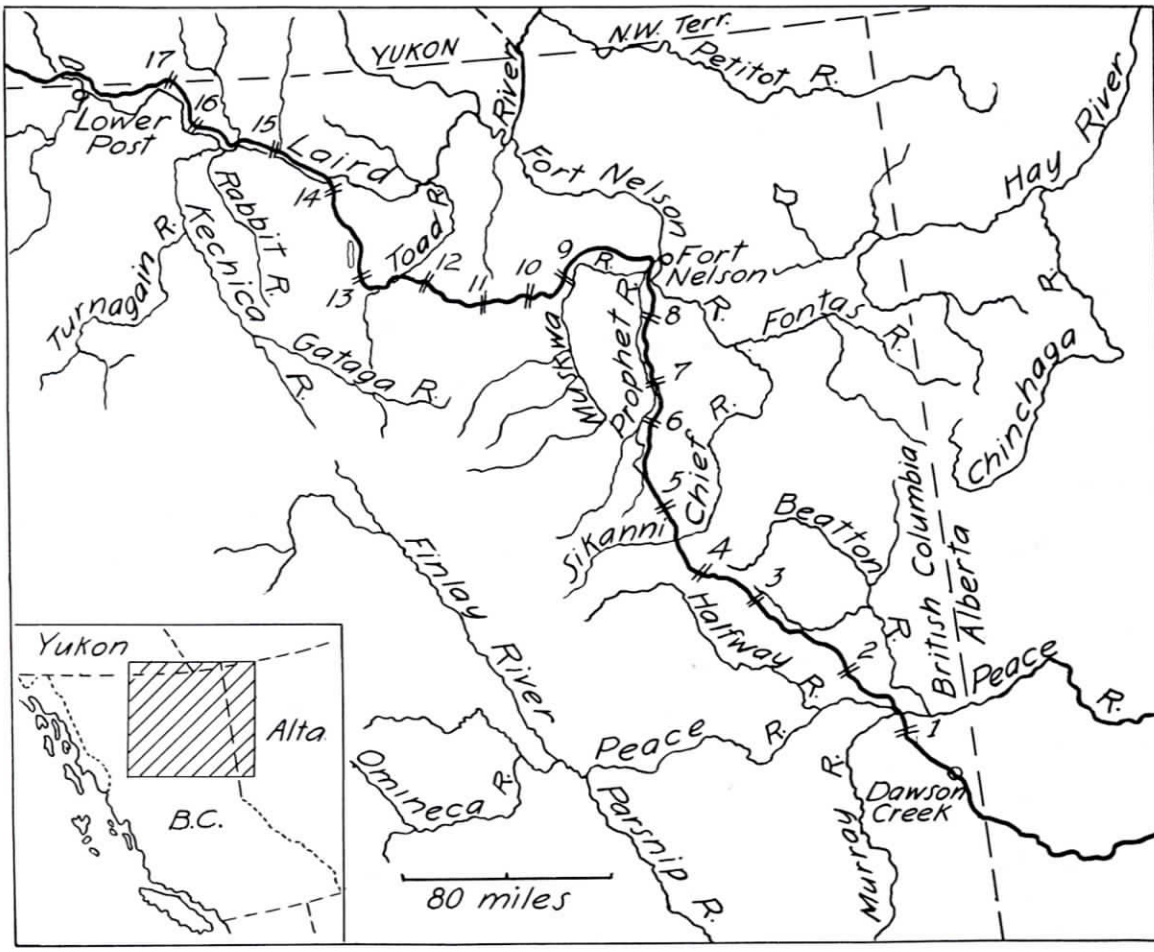


FIG. 1. Map of northeastern British Columbia showing Alaska Highway and the location of 17 sites from which peat sections were obtained for pollen analysis. Double lines crossing highway indicate location of muskegs.

shield occur along the Alaska Highway at 58° 40′ within five miles of the Rocky Mountains.[2] It is not known whether the Cordilleran and Keewatin glaciers coalesced during any of the glacial stages. As this region is near the border of both ice sheets, the ice was probably much thinner than toward the centers of accumulation. The Cordilleran glacier was probably lesser in extent and thickness because of the low precipitation on the east slope of the Rockies, and it is possible that ice-free areas existed at times during the Late Wisconsin glaciation and at least early during its recession. This possibility is increased by the fact that the upper Yukon River valley in south central Yukon was unglaciated. Apparently the Cordilleran glacier was insufficiently nourished to permit its extension into this area. The position of the Late Wisconsin Altamont (Mankato) moraine in eastern Alberta indicates that an extensive ice-free area probably existed in western Alberta during the last glacial stage.[3,4] How far northwestward this ice-free corridor extended is unknown, but the thinness of the ice in the region of this study suggests the possibility of its early postglacial junction with the unglaciated region in the upper Yukon River valley. The writer believes that forests persisted in ice-free areas in western Alberta during the Late Wisconsin glaciation and permitted early postglacial invasion of adjacent deglaciated terrain.

[2] *Ibid.*

[3] Cameron, A. E., Postglacial lakes in the MacKenzie River basin, Northwest Territories, Canada, *Jour. Geol.* **30**: 337–353, 1922.

[4] Bretz, J. Harlan, Keewatin end moraines in Alberta, Canada, *Bull. Geol. Soc. Amer.* **54**: 31–52, 1943.

The term "postglacial" as used in this paper refers to the time since areas within range of pollen dispersal to the sites of the sediments became ice-free. Postglacial forests began not earlier than deglaciation, while their pollen record may have been delayed somewhat by the absence of early postglacial sedimentation favorable for the reception and preservation of pollen grains. The age of the forests represented by the pollen profiles in this study is unknown and there seems to be little or no basis at present for an estimate. However, a few chronological considerations are mentioned later in the paper.

METHODS AND TECHNIQUE

In preparation of the sediments for pollen analysis, the potassium hydrate method was used.[5] From 100 to 200 pollen grains were identified from each level except those from the underlying clay and silt in sections 1 to 10, which contain little or no pollen (table 1). The absence of pollen of hydrophytic plants such as cat-tail, sedges, and water lily in the lower horizons, as well as the absence of algae and limnic peat underlying the fibrous peat, indicates there were no initial aquatic stages of hydrarch succession. These factors and the general paucity of pollen in the silt and clay sediments suggest that the pollen profiles constitute a record beginning with the earliest forests in the region. In many of the sections volcanic glass was noted at or near the top (table 1). It is conceivable that the glass came from the eruption of Mount Katmai, Alaska, which occurred in 1912. Glass was also noted near the top in sections from western and central Alberta.[6, 7] The average thickness of the seventeen sections is only 2.0 meters with about 1.7 meters of organic sediments. The thickest section south of Fort Nelson at mile post 253, consists of over 6 meters of good Sphagnum peat. No regional pattern is exhibited with respect to depth, the one farthest north at mile post 580 being 4.2 meters and the one farthest south near Dawson Creek at mile post 28 being 4.0 meters. The average depth of seven bogs near Edmonton, Alberta is 3.0 meters suggesting more favorable conditions for peat accumulation with decrease in latitude.

Pollen grains are abundant in the fibrous peat, with those from coniferous species being by far predominant. Although tamarack is common on the muskegs, pollen in the upper levels is scarce, indicating that this species is under represented. In addition to coniferous pollen, other plants represented are water lily, members of the Ericaceae family, alder (*Alnus* sp.), willow (*Salix* spp.), birch, poplar(sedges, composites, chenopods, grasses, cat-tail, sundew, and *Epilobium* sp.

FORESTS ALONG THE ALASKA HIGHWAY

The Alaska Highway in northeastern British Columbia follows the eastern flank of the Rocky Mountains for the first 300 miles to Fort Nelson (fig. 1). The route then swings almost due west for about 150 miles as it enters the Rockies. It then turns northwest to continue its path through the more rugged and easterly drained section, following up the Laird River valley to Lower Post near the Yukon border. From Dawson Creek to Fort Nelson, the highway passes through an area of rolling topography, and as it enters the Rocky Mountains the topography becomes more precipitous with greater relief.

The Alaska Highway in British Columbia lies within but near the western border of the boreal forest which extends across Canada from Labrador to Alaska.[8] Two of the important forest trees of this formation, however, do not range this far west and are apparently absent in the forests along the highway. These are balsam fir (*Abies balsamea*) a climax dominant, and jack pine (*Pinus banksiana*) a subclimax species that thrives as result of fire and in sandy areas. Another climax dominant, white spruce (*Picea glauca*) and its varieties, is probably the most abundant tree along the highway. Other species of the boreal forest present are black spruce (*Picea mariana*), tamarack (*Larix laricina*), balsam poplar (*Populus tacamahacca*), and paper birch (*Betula papyrifera*). Aspen (*P. tremuloides*), an important subclimax tree in the boreal forest which thrives as a result of fire and clearing, is abundant. Two other species, alpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta* var. *latifolia*) grow in the region which the highway traverses. Both of these species are Cordilleran species and constituents of the subalpine forest.[9] This climax is contiguous

[5] Hansen, H. P., Postglacial forest succession, climate, and chronology in the Pacific Northwest, *Trans. Amer. Philos. Soc.* **37**: 1–130, 1947.

[6] Hansen, H. P., Postglacial forests in south central Alberta, Canada, *Amer. Jour. Bot.* **36**: 54–65, 1949.

[7] Hansen, H. P., Postglacial forests in west central Alberta, Canada, *Bull. Torrey Bot. Club* **76**: 278–289, 1949.

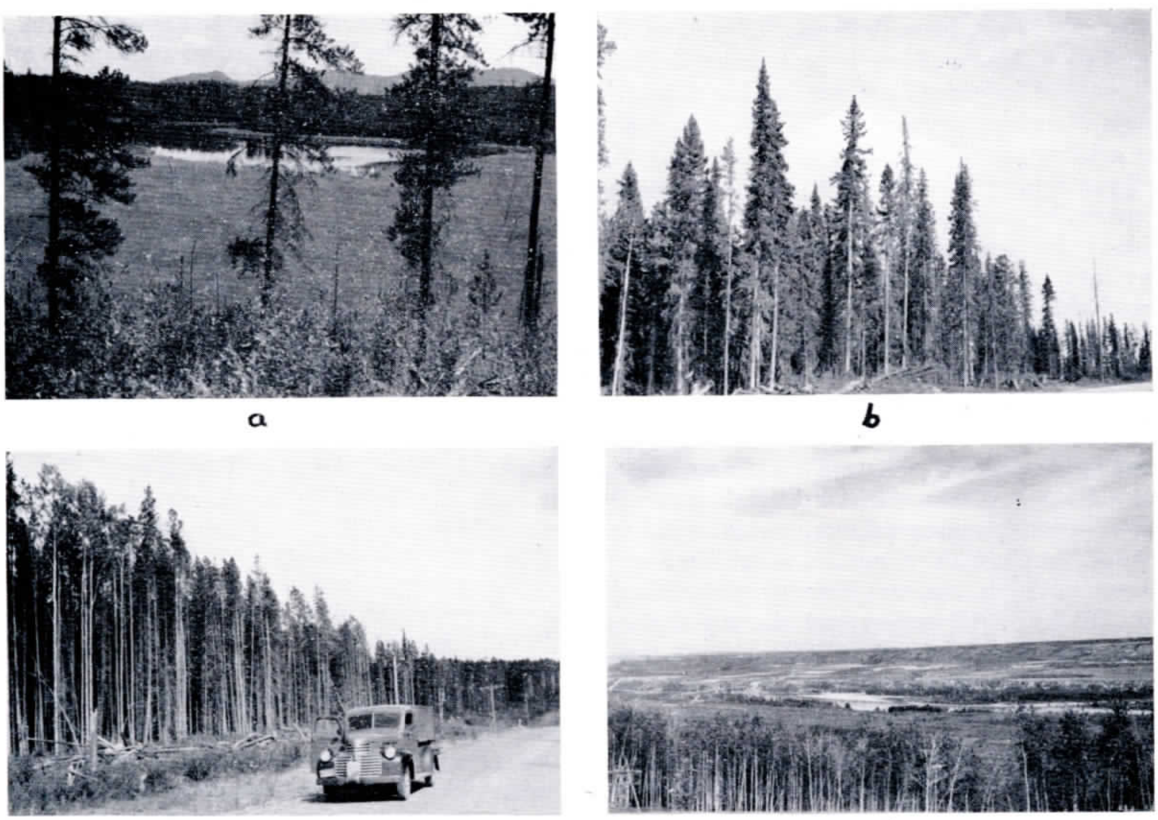
[8] Weaver, J. E., and F. E. Clements, *Plant ecology*, N. Y., McGraw-Hill, 1938.

[9] *Ibid.*

with the boreal forest and these two species range far eastward within the latter, forming a broad ecotone. Alpine fir is uncommon but lodgepole pine is probably next to white spruce in abundance. Thus the forests along the Alaska Highway in British Columbia, a distance of about 600 miles, are composed largely of eight arborescent species.

General observation of the forest composition as one drives along the highway leaves the feeling that the species listed above occur in practically any combination with little regard for soil, topography, slope, exposure, and other environmental factors. Furthermore, the many and recurring combinations of these species give the impression that there is little variation in the over all forest structure and composition with an increase in latitude. The writer does not pretend to have made a thorough investigation of the forest composition along the highway and his observations are confined chiefly to a narrow bordering zone. Even this hasty and general survey, however, revealed a certain degree of consistence in composition and structure which portray a fairly systematic relationship between forest succession, tree requirements, and the environment.

The most common trees are white spruce, lodgepole pine, and aspen, and probably in that order of abundance. Of these, white spruce is the most permanent and may be considered as a climax dominant. It reaches its greatest development and occurs most widely on well-drained upland sites and the lighter floodplain alluvial soils (fig. *2b*). Lodgepole and aspen owe their persistence largely to fire, and where they have grown sufficiently to shade the forest floor they are not reproducing to any great extent (fig. *2c*). Likewise they are not reproducing in the undisturbed white spruce stands. On sandy outwash, lodgepole pine seems to have developed some degree of permanence, particularly in the vicinity of and south of Watson Lake. The absence of fire or other disturbance factors for several centuries would un-



a b c d

FIG. 2. *a*, Sedge and Sphagnum bog at mile post 580, from which section No. 17 was obtained. Lodgepole pine in foreground. *b*, Climax forest of white spruce. *c*, Pure stand of lodgepole pine along Alaska highway. *d*, Aspen groves near Peace River about 30 miles north of Dawson Creek.

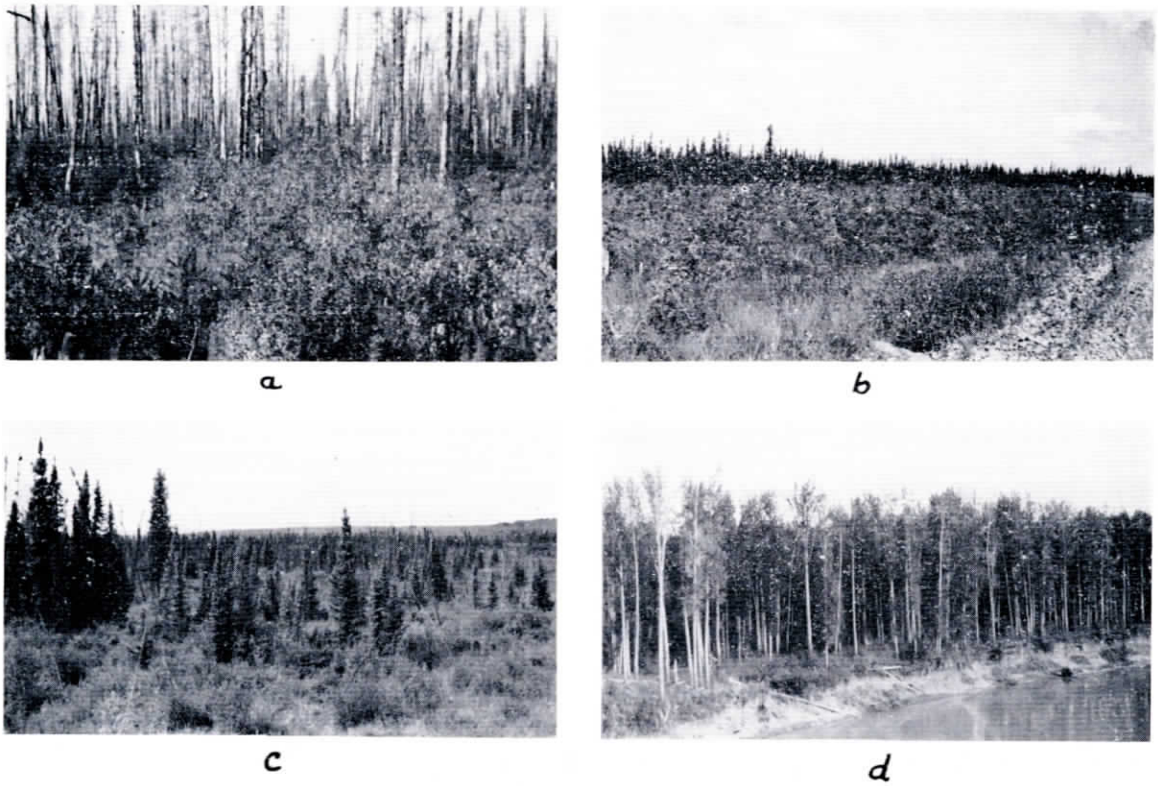


FIG. 3. *a*, A burned-over spruce stand, with aspen and lodgepole pine invading in the foreground. *b*, Muskeg at mile post 253, 7 meters deep. *c*, Typical muskeg along Alaska Highway with black spruce. *d*. Balsam poplar on floodplain of Muskwa River, near Fort Nelson.

doubtedly culminate in practically a pure stand of spruce, which would persist indefinitely with no change in environment. Aspen also appears to be somewhat permanent in prairie-like areas about Fort St. John near the southern terminus of the highway (fig. *2d*). The successional status of these two species in relation to fire and their present distribution indicate that fire has played an important role in the past as well as in the present. Practically all stages of succession initiated by fire can be seen along the highway (fig. *3a*).

The next most important tree is black spruce which occurs commonly on muskegs and bogs as a seral dominant, but it also seems to be climax on the mountain slopes and plateaus where it is associated with white spruce and lodgepole (figs. *3b*, *3c*). The most extensive areas of this forest complex are to be found about 50 miles north of Fort St. John from where it extends for about 150 miles northward and between Summit Pass and the lower crossing of the Laird River.[10] Tamarack is abundant locally where it occurs with black spruce on muskegs, but it was noted to be abundant in upland forests in the vicinity of mile post 560. The remaining conifer, alpine fir, is uncommon along the highway, but occurs at higher altitudes west of Fort Nelson and in the Rocky Mountains still farther to the west. Although alpine fir is a climax species, it has never been abundant in the forest complex as will be shown later. Balsam poplar was noted chiefly on sandy floodplains where it forms pure stands or is associated with white spruce (fig. *3d*). It is not a climax species and seems to be a seral unit in early stages of white spruce forests on the lighter soils and floodplains. In the Peace River region an abundance of balsam poplar associated with white spruce and aspen on upland sites was noted by Raup.[11] Paper birch is the least abundant of the arborescent species in the forests along the highway, and it was noted in sporadic and small stands west and north of Fort Nelson. Paper birch was noted on burned-over

[10] Raup, Hugh M., Forests and gardens along the Alaska Highway, *Geogr. Rev.* **35**: 22–48, 1945.

[11] *Ibid.*

muskegs, and it is generally regarded as a fire subclimax species in the boreal forest.

According to Halliday's forest classification for Canada the Alaska Highway in British Columbia traverses the Aspen Grove, the Mixed-wood, the Foot-hills, and the Upper Laird sections.[12] The Aspen Grove section, characterized by patches of aspen in pairie-like areas has its most northwestern outlier in the Fort St. John and Dawson Creek region. The Foot-hills section occurs in the foothills of the Rocky Mountains and may be considered as an ecotone between the subalpine and the boreal forests. Alpine fir and lodgepole pine from the former and white and black spruce of the latter, and aspen are present. Lodgepole is very abundant on burns. The Mixed-wood section is a mixture of aspen, white and black spruce, balsam poplar, and lodgepole pine. The Upper Laird section, occupying the Laird River drainage for the last 150 miles of the highway in British Columbia, is characterized by white spruce, lodgepole, and aspen, with alpine fir on upper slopes and black spruce and tamarack on bogs. The foregoing description of the forest composition and structure is very general, but a more detailed account is hardly necessary as far as pollen analysis is concerned.

INTERPRETATION OF THE POLLEN PROFILES

The interpretation of the pollen profiles of this study directly into terms of forest succession and paleic composition must be qualified in general by the same conditions and factors involved in palynological studies in any region. However, there are several factors that prevent the portrayal of a complete and accurate picture that are obvious and should be mentioned. Perhaps the most important is the almost complete absence of *Populus* pollen in the sedimentary columns as indicated by pollen analysis. It is well known that pollen of this genus is not well preserved in peat, which is unfortunate because of the importance and abundance of aspen and balsam poplar both present and probably in the past in this region. The successional relationship of aspen to pine and spruce after fire would undoubtedly be expressed many times in the sections if its pollen were representatively preserved. Although some *Populus* pollen was identified, its occurrence is sporadic and sparse in the sections, and does not present relevant trends. Birch pollen is fairly consistently and abundantly present, but interpretation of its fluctuations in terms of forest succession is not feasible because of the prevalence of bog and paper birch on the muskegs and the occurrence of the latter in the adjacent forests. Although the size ranges of bog and paper birch pollen may vary sufficiently to permit separation, the writer has not investigated this possibility. Measurement of fossil birch pollen on the microscope slides, however, did not reveal much variation in size. A third factor that influences interpretation of pollen profiles is the occurrence of black spruce on the muskeg surface as well as in the upland forest. Although there is a distinguishable difference in the size range of the pollen of black and white spruce, their individual pollen profiles fluctuate so widely from level to level as to make interpretation both unwieldy and impractical. The trends as exhibited by all spruce pollen in a single profile seem to be less fluctuating and erratic as well as more logical. A fourth influence upon the degree of accurate representation is the greater amount of pollen produced by lodgepole pine than the other coniferous species. This is magnified by the early age at which it begins to shed pollen. Where the proportion of lodgepole pollen is similar to that of another species, it probably should be assumed that the other species is the more abundant within the range of pollen dispersal.

The absence of pollen from other species in significant proportions causes the pollen profiles of spruce and pine to fluctuate conversely to each other. The proportions of alpine fir pollen being low means that pollen profiles of spruce and pine are almost entirely reciprocal to each other as the sum of the two at a given horizon constitutes approximately one hundred per cent. These fluctuations from level to level must in some cases, at least, be considered as merely relative. That is, if one species was decimated in abundance by fire, the pollen record of the other immediately increased for that period without necessarily an actual increase in its abundance. While this is true also when several species are represented, the implications are magnified when only two species are involved. If the profiles of spruce and pine for each section are placed face to face, the curves fit together very closely. Any slight deviation is due to the low proportions of alpine fir.

The relative trends of the spruce and pine pollen profiles fall into several significant general patterns briefly discussed here, while other noteworthy features are shown in table 2. Perhaps one of the

[12] Halliday, W. E. D., A forest classification for Canada, Dept. Mines and Resources, *Can. For. Serv. Bull.* **89**: 1-50, 1937.

TABLE 2

TRENDS AND FEATURES OF POLLEN PROFILES OF PEAT SECTIONS ALONG THE ALASKA HIGHWAY

Trend or feature	No.	Sections in which it occurs
Spruce predominant at bottom	(14)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 17
Spruce predominant throughout	(6)	6, 7, 8, 9, 10, 12
Spruce predominant at top	(7)	6, 7, 8, 9, 10, 12, 14
Spruce predominant in lower half with pine increasing in upper half to become predominant at top	(7)	2, 3, 4, 5, 11, 16, 17
Spruce increment in upper few levels	(4)	7, 8, 12, 15
Spruce decline in upper few levels	(13)	1, 2, 3, 4, 5, 6, 7, 9, 10, 14, 15, 16, 17
Pine predominant throughout	(3)	1, 13, 15
Pine predominant at bottom	(3)	1, 13, 15
Pine predominant at top	(10)	1, 2, 3, 4, 5, 11, 13, 15, 16, 17
Pine increment in upper levels	(13)	1, 2, 3, 4, 5, 6, 9, 10, 11, 14, 15, 16, 17
Pine minimum between bottom and top	(11)	1, 2, 3, 7, 8, 9, 10, 11, 12, 16, 17
Pine generally increasing throughout	(3)	4, 5, 6
Pine showing higher proportions at top than bottom	(14)	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 16, 17

more significant and regional trends is the general expansion of spruce upward from the bottom to its maximum in the lower or middle third of the profile and then its decline to its minimum at or near the top in eleven sections (figs. 4, 5, 6, 7). Fourteen sections manifest spruce predominance when the lowest pollen-bearing sediments were deposited, indicating that this species was the most abundant postglacial pioneer invader in the region. On the other hand, thirteen sections exhibit pine expansion in the upper levels, while conversely, spruce declines in an equal number of profiles in the same horizons (figs. 4, 5, 6, 7, 8). In fourteen sections pine shows higher proportions at the top than the bottom. The recorded expansion of pine in the upper strata indicates a widespread and consistent development of favorable conditions for this species during the past several centuries or possibly the last millennium. Seven sections reveal spruce as predominant in the lower half with pine increasing in the upper half to become predominantly recorded at the surface. In six of these, the proportions of pine in the upper horizons are sufficient to suggest its actual predominance in the region in recent time (figs. 4, 5). Six sections express preponderance of spruce throughout, including the thickest of 6.6 m. at mile post 253. In only three sections is pine represented in higher proportions than spruce throughout (fig. 8), while in three others pine shows a generally constant expansion from bottom to top (figs. 4*A*, 4*B*, 7*B*). A single section reveals spruce and pine as co-abundant throughout, although the relative amounts of pollen shed by the two species suggest that spruce was actually the more abundant.

A fair degree of consistency exists with respect to the overall, general patterns and trends, as well as the more specific, localized trends, in relation to the location of the sections along the highway. In general, there has been a preponderance of spruce over most of the region, during the time

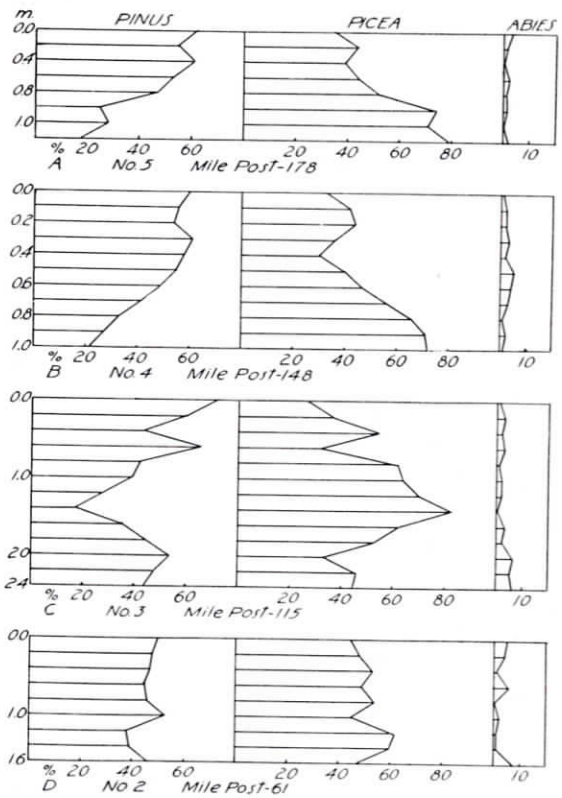


FIG. 4. Pollen diagrams of four muskegs along Alaska Highway.

represented by the seventeen sections. However, there was a decline in spruce after its maximum attained sometime after the invasion of postglacial forests, which reflects a systematic, widespread, regional influence at play. An expansion of pine after it had declined upward from the bottom to its minimum in the lower or middle third of most sections was obviously caused by the same influence responsible for the spruce decline. Sections 6, 7, 8, 9, 10, and 12 exhibit spruce predominance throughout, indicating that from mile post 230 to 415, forests have been and are chiefly composed of spruce. Of the seven sections revealing pine predominance in the upper half or third, only 2, 3, 4, and 5, from mile post 61 to 178, denote pine preponderance over an appreciable continuous area. Many of the pine profiles could almost be superimposed upon one another, and, allowing for differences in rate of accumulation or age of the sections, very similar and apparently synchronous fluctuations should be shown. The spruce profiles, being the converse of those of pine, also express a high degree of correlation, with the spruce

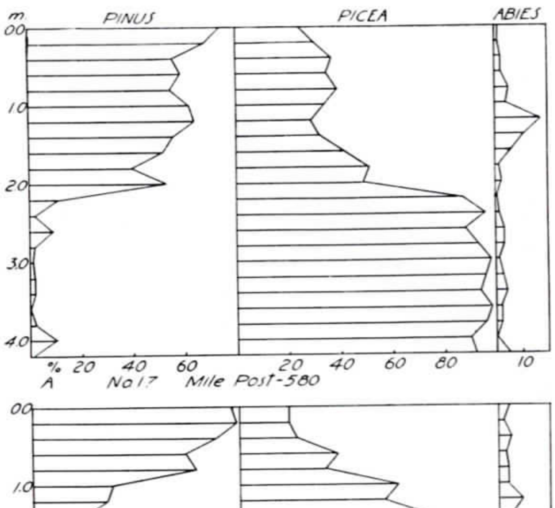


FIG. 5. Pollen diagrams of three muskegs along Alaska Highway. Spruce predominant at bottom, lodgepole predominant at top.

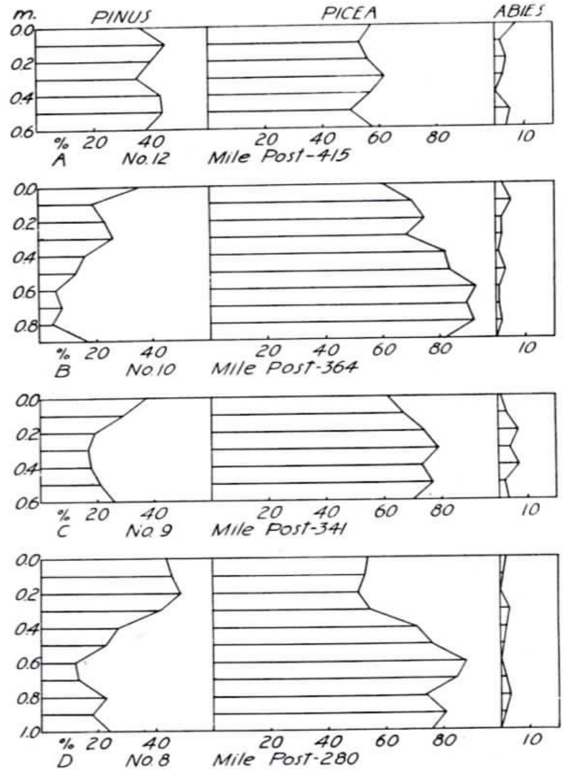


FIG. 6. Pollen diagram of four muskegs along Alaska Highway. Spruce predominant throughout.

maximum occurring at about the same horizon as the pine minimum. In most of the sections, pine shows similar fluctuations in the upper levels; with an increase, then a decline, and again an increase to the top. The converse, of course, is true of spruce. The thickest section shows by far the greatest and most sustained preponderance of spruce, with proportions ranging between 85 and 98 per cent for two thirds of its profile (fig. 7*A*). The maximum proportion attained by spruce is 98 per cent in sections 7 and 17. The average of the spruce maxima in the 17 profiles is about 71 per cent. A pine maximum of 79 per cent is reached in sections 13 and 16, while the average for its maxima in all sections is about 58 per cent.

The pollen profiles of alpine fir show no consistent regional trends. This tree, not being abundant in the forest complex, and found most commonly on the upper slopes near timberline, is poorly represented. In general, it is best recorded in sections from bogs along the northern half and more mountainous portion of the highway. In only five sections does it manifest a gradual decline from bottom to top. Its maximum of 19 per cent occurs in the lower levels of the deepest section, while its strongest sustained representation is expressed in section 16 (figs. 7*A*, 5*B*). Although there seems to be little correlation between the fluctuations of fir and pine or spruce, its greatest reciprocity apparently is to spruce. In many instances, an increase in fir is synchronous with spruce decrease, but there is little correlation between fir and pine.

A combination of several factors may have influenced postglacial forest succession in northeastern British Columbia. These include disease, fire, climatic fluctuations, and physiographic instability. Climate and physiographic-edaphic instability probably were more influential during the first two-thirds of the time represented while fire has played the more important role in more recent time. In all but three sections spruce is predominantly recorded in the lowest pollen-bearing level. The initial preponderance of spruce in the region may reflect the cooler and moister climate attendant

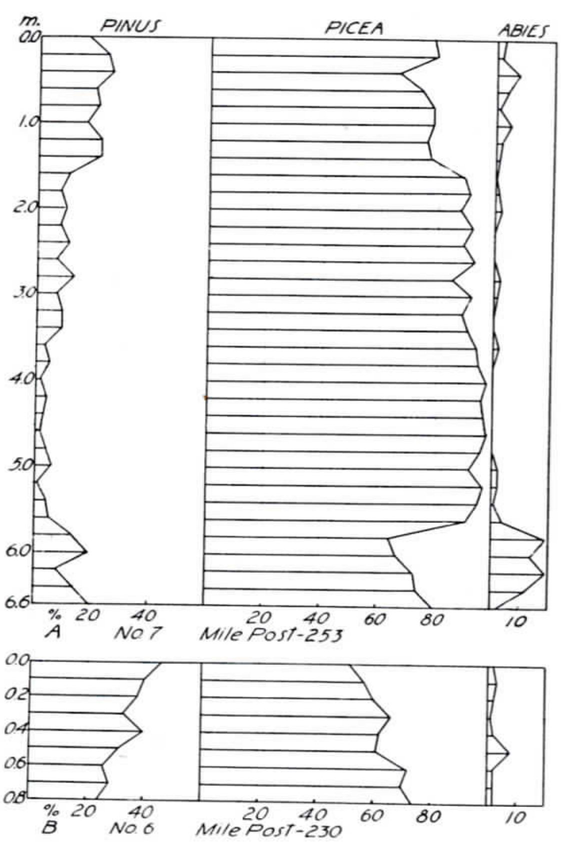


FIG. 7. Pollen diagrams of two muskegs along Alaska Highway. *A*, Deepest muskeg sectioned, showing predominance of spruce throughout, and maximum spruce proportions.

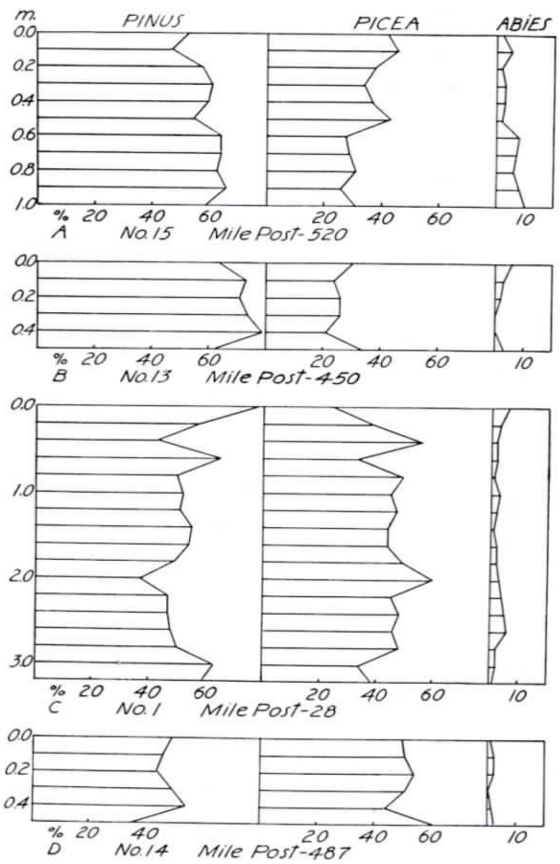


FIG. 8. Pollen diagrams of four muskegs along Alaska Highway. *A*, *B*, *C* show general predominance of pine throughout.

in the wake of deglaciation, as well as the possible persistence of spruce nearer to the region in ice-free areas. However, the appreciable proportion of pine in the initial postglacial forests probably resulted from the unstable physiographic and edaphic conditions persisting from deglaciation. The much younger age at which pine produces seed would normally be favorable for its more rapid migration than spruce if climatic and edaphic conditions were suitable, and if it existed in nearby unglaciated areas. This is well shown in the Puget Lowland of western Washington, where lodgepole pine was regionally and consistently the chief, pioneer, postglacial invader, although both Douglas fir (*Pseudotsuga taxifolia*) and western hemlock (*Tsuga heterophylla*) were in the vicinity.[13] The expansion of spruce to its maximum in the middle third of most sections indicates con-

[13] Hansen, H. P., Postglacial forest succession, climate, and chronology in the Pacific Northwest, *Trans. Amer. Philos. Soc.* **37**: 1–130, 1947.

tinued favorable conditions for this species, which may have been sufficient moisture and a fire-free period of considerable duration. Pine declined during this same period as the physiographic-edaphic conditions became more stabilized and in the absence of fire essential for its reproduction. Expansion of pine in the upper half of most sections may denote a dryer climate during the last few millennia which in turn increased the frequency and extent of fire, both of which further favored it over spruce. In those sections in which pine is predominantly recorded throughout, the influence of local fire may have been responsible.

The hypothetical postglacial status of aspen in the region must be considered even though its pollen record is negligible. Observations of the present forests along the Alaska Highway reveal that aspen is often the first arboreal invader after fire. After several fires at frequent intervals, it may occur in almost pure stands because of its habit of sprouting from the roots. It is possible that during the time of the pine minimum and spruce maximum aspen was abundant in the area but because of poor pollen preservation it is not represented. White spruce, occupying unburned areas, and black spruce, growing on muskegs, may be over represented in the absence of aspen pollen. As pine replaced aspen on older burns, it became more abundantly represented while spruce remained more or less static. Likewise, during its maximum, pine also may have been over represented at the expense of aspen, although aspen may not have been as abundant as during the spruce maximum. The absence of balsam poplar pollen may also cause over representation of spruce and pine in certain areas, particularly along the floodplains of the Prophet and Laird Rivers.

The general age of the sedimentary columns of this study, the time of deglaciation, and how soon after deglaciation the region was invaded by forests is difficult to estimate. The following analyses and interpretation of the data are tentative until further studies are made in this and contiguous regions. As mentioned above, the average depth of the seventeen sections of this study, including the underlying clay, is 2.0 m. The average depth of thirty sedimentary columns in the Pacific Northwest of the United States resting upon glacial drift or its chronological equivalent is about 7.2 m.[14] The age of these sections is set at about 18,000 years and the average rate of deposition of the pollen-bearing sediments is computed at about 1 meter per 2,500 years. The same rate applied to the average thickness of the sections of this study gives an age of about 5,000 years. The rate of deposition had undoubtedly been slower at this latitude, however, and the thicker sections may be older than 5,000 years. Seven meters of unfrozen sediments at mile post 253 of which 6.6 m. are pollen-bearing and more than 4.0 m. at mile post 580 near 60° latitude denote a long period of time under the short growing season. The rate of deposition of a 39-foot section of peat near Russell Glacier in Alaska has been computed by Capps at one foot per 200 years.[15] The 7,800 years estimated for the age of the section may be considered as the approximate time since deglaciation.[16] However, this peat bed is frozen to within six inches of the surface which denotes less favorable conditions for accumulation than in the area of the present study where only two muskegs were found to be frozen near the bottom.

The writer is of the opinion that the region within range of pollen dispersal to the sites of the sediments of this study was forested soon after deglaciation. The area along the first 300 miles of the highway, east of the Rockies, lies near the western margin of the Keewatin ice and the eastern edge of the Cordilleran glacier. The ice along these termini must have been thin, with ice-free areas appearing early during glacial retreat, or even at times during glaciation, when the two glaciers failed to coalesce along their entire fronts. Furthermore, ice recession may have begun earlier than in regions where the ice was thicker. How far northwestward the ice-free corridor in western Alberta extended is problematical, but the abundance of lodgepole pine in the earliest postglacial recorded forests along the highway suggests that extreme boreal conditions did not exist. The high proportions, and in some cases, the predominance of pine in early postglacial or Late Wisconsin (Mankato) forests in the vicinity of Edmonton, Alberta, is consistent with the position of the Altamont (Mankato) moraine 75 miles east of Edmonton.[17] Apparently an ice-free corridor, 100 or more miles in width, existed between the Keewatin and Cordilleran ice during the Late Wisconsin glaciation. The abundance of spruce and pine in these forests as indicated in the lowest horizons of

[14] *Ibid.*

[15] Capps, S. R., The Chisana-White River district, Alaska, *U. S. Geol. Surv. Bull.* **630**: 130, 1916.

[16] Flint, R. F., *Glacial geology and the Pleistocene epoch*, N. Y., Wiley, 1937.

[17] Bretz, J. Harlan, Keewatin end moraines in Alberta, Canada, *Bull. Geol. Soc. Amer.* **54**: 31–52, 1943.

peat bogs in the region, suggests that this ice-free area was forested during Late Wisconsin time or soon thereafter.[18, 19] The climate apparently was not so severe as farther eastward in the Great Lakes region, where the initial postglacial forests consisted largely of spruce.

The pollen profiles of this study tend to support Hultén's theory with respect to the survival of boreal biota in ice-free areas during the last Wisconsin glaciation.[20] These refugia served as centers of forest migration into progressively deglaciated regions. The most significant refugium in regard to this study is located in the upper Yukon River Valley in west central Yukon Territory, which apparently was not glaciated. The region about the Bering Sea was also unglaciated including central Alaska, the latter of which is continuous with the Yukon area. White and black spruce, tamarack, lodgepole pine, alpine fir, paper birch, and aspen are thought to have persisted in these areas during the Late Wisconsin glaciation whence they migrated outward soon after ice retreat. How extensive an ice-covered area separated the unglaciated portion of Yukon Territory and the ice-free corridor of western Alberta during the Late Wisconsin glacier is at present conjectural. The high proportions of lodgepole pine in the initial postglacial forests along the Alaska Highway in British Columbia indicate the existence of nearby forests containing this species. Whether pine and spruce, migrating northward from western Alberta or southward from the Yukon, were the first to reach this area is impossible to say. If the climate was sufficiently mild for these species to persist in the Yukon during Late Wisconsin glaciation, there is no reason to assume they did not migrate into adjacent deglaciated areas as rapidly as their life cycles would permit.

The absence of driftwood in the older deltas and beaches in the Athabaska-Great Slave Lake region as compared to its abundance in more recent similar deposits has been interpreted by Raup to indicate the absence of extensive forests in the Peace and Athabaska River basins until the postglacial warm, dry maximum between 8,000 and 4,000 years ago.[21] However, this is negative evidence. There are hundreds of miles between west central Alberta and northeastern British Columbia and this northern great lakes region. The existence of many large lakes during the late glacial stages must have provided ample opportunity for deposition of driftwood by streams before they emptied into the Athabaska-Great Slave Lake complex. Peat bogs in western Alberta with 7 m. of sediments containing pine and spruce pollen at the bottom denote a long period of time and point to either the persistence of forests in this region during Late Wisconsin glaciation or appearance early in postglacial time. The author prefers the former interpretation. The forests along the Alaska Highway in British Columbia obviously did not persist there during the last glaciation, but there apparently was opportunity for them to invade the area almost upon the heels of the retreating ice.

SUMMARY

Pollen analysis of seventeen peat sections from bogs and muskegs located along the Alaska Highway in British Columbia reveals that white and black spruce and lodgepole pine were the predominent pioneer, postglacial, arboreal invaders in the region. Spruce apparently was more abundant than pine and remained so for a considerable time, gradually expanding in the absence of fire and as the unstable physiographic conditions left in the wake of the retreating ice were stabilized. As the climate became warmer and dryer, pine expanded to become almost co-abundant with spruce over much of the region in recent time. It seems probable that extensive and frequent fires played a more important role than climatic trends in pine expansion, because under the present climate spruce is climax and forms pure stands and persists in the absence of the pyric factor. Although alpine fir is represented consistently throughout all sections, no definite or pertinent trends seem to be depicted in its pollen profiles. The thickness of some of the sedimentary columns and the early invasion of pine suggest to the writer that ice-free areas in western Alberta, during the Late Wisconsin glaciation, served as refugia for forests during this time and as centers of migration northwestward early during postglacial time. Likewise the unglaciated portion of the Yukon Territory and Alaska may have supported forests which spread southward as northern British Columbia became deglaciated.

[18] Hansen, H. P., Postglacial forests in south central Alberta, Canada, *Amer. Jour. Bot.* **36**: 54–65, 1949.

[19] Hansen, H. P., Postglacial forests in west central Alberta, Canada, *Bull. Torry Bot. Club* **76**: 278–289, 1949.

[20] Hultén, Eric, *Outline of the history of arctic and boreal biota during the Quaternary period*, Stockholm, 1937.

[21] Raup, Hugh M., Phytogeographic studies in the Athabaska-Great Slave region II. Forests, *Jour. Arnold Arb.* **27**: 1–85, 1946.