GLACIER FLUCTUATIONS IN THE CANADIAN ROCKIES

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Synopsis

Through the use of survey and botanical techniques, recent glacier fluctuations in the Canadian Rockies were measured and dated. Twelve glaciers in British Columbia and Alberta were studied between the Mount Robson area in the northwest and the vicinity of Kicking Horse Pass in the southeast. Two of them, Robson and Yoho Glaciers, are on the western slopes; ten, Angel, Columbia, Dome, Athabaska, unnamed at the head of Hilda Creek, Saskatchewan, Southeast Lyell, Freshfield, Peyto, and Bow Glaciers drain on the east. Some of these flow from the same ice field, some from independent névés, and some are merely hanging ice masses.

Glacier advances are dated from ice-tilted trees, glacier retreat from the age of trees that have become established on recessional moraines. Records of this study show that glaciers attained maxima and receded between the late seventeenth and late nineteenth centuries. Bow Glacier receded as early as 1673; six glaciers receded from maxima in the eighteenth century and five withdrew during the nineteenth century. These data compare with results of similar studies elsewhere in British Columbia, in Oregon, and in Alaska. No evidence of major twentieth century advance was observed as is known for certain coastal Alaskan glaciers.

Introduction

This paper constitutes a report of the 1953 field work on twelve glaciers draining the northeast and southwest slopes of the Rocky Mountains in Alberta and British Columbia, Dominion of Canada. The purpose of the study is to record and date the fluctuations which have occurred in this region for comparison with those in other glacier areas on North America and elsewhere on the erarth. Although field data are yet being checked and a final treatment of the study is being prepared, this paper is reported here so that preliminary findings can be made available for this conference. The program was carried out jointly with Mr. William O. Field of the American Geographical Society and with the aid of two assistants. Mr. Field conducted the survey, photographic, and map compilation while the writer dated the recent variations by means of botanical methods. The research was supported by the Glacier Study Project of the American Geographical Society and the Penrose Fund of the American Philosophical Society.

The twelve glaciers for which data were obtained are between the Mount Robson area in the northwest and the vicinity of Kicking Horse Pass to the southeast. This region is approximately 175 miles along the main range. Robson and Yoho Glaciers are on the western side; Angel, Columbia, Dome, Athabaska, unnamed at the head of Hilda Creek, Saskatchewan, Southeast Lyell, Freshfield, Peyto, and Bow Glaciers drain to the east. Systematically, Columbia, Athabaska, Dome, and Saskatchewan emanate from the Columbia Icefield; Peyto, Bow and Yoho originate in the Wapta Icefield. The other glaciers considered have their source regions in independent ice fields or may be small hanging masses, much reduced from their former size. The region is divided into Mount Robson Provincial Park and Jasper, Banff, and Yoho National Parks.

Observations of glacier fluctuation in the Canadian Rockies were first made by early travelers in the nineteenth century. Records of these and others since have been kept in the form of measurements and photographs largely by workers connected with the Alpine Club of Canada and the Dominion Water and Power Bureau. Few individuals have made use of botanical methods, and Cooper's (1916) plant succession study at Robson Glacier is particularly noteworthy. The reason for this is that the procedures and the kind of information that could be obtained

were not widely known. Lawrence (1950*a*) has brought together a conspectus outlining the methods. These were utilized for obtaining the results to be presented later. A summary follows for the purpose of acquainting those who are unfamiliar with the work with this approach to dating.

Botanical Methods

Glaciers that have flowed down forested valleys have removed or buried the vegetation in their line of advance. After the ice has retreated from its maximum position, the edge of the forest bordering the terminal or lateral moraines or the outwash is usually sharply defined. This border outlining the former extent of the ice is called the trimline. The characteristics of the trees along the trimline afforded the necessary source material for determining the most recent advance and recession.

Trees that were tilted by the forward motion of the glacier some time in the recent past usually appear bowed. If trees that have been pushed over survive, they will endeavor to grow erect and in doing so, will exhibit a curved trunk. The date of ice push can be determined from the annual growth rings and the form of the growth outline shown in a cross section of the tree. Previous to glacier advance the annual layers are generally produced concentrically with more or less equal circumferential material being laid down. Following tilting the pattern of growth changes and becomes eccentric. Thin layers are produced on the upper side of the trunk and thick layers on the underside in coniferous trees; in broadleaved species this condition is reversed, that is, thick layers grow uppermost and thin layers are below. In studying such trees care is taken in not confusing glacier-pushed specimens with those that may have been tilted by snow creep, avalanching, frost action, or some related process. Certain trees may show ice scars; the push was insufficient to incline the tree, but the trunk was injured. Such injury can be dated by counting the annual rings produced since healing.

Trees in the old forest outside the trimline can also be cut in order to determine their ages. A much simpler procedure, however, is to core the base of the tree through to its growth axis using a Swedish increment borer. The ages of the oldest trees offer a minimum time since ice could have been further advanced than the existing trimline. Cores from these trees can also be studied and the growth increments measured. The period during which ice was nearby is usually expressed by a change in growth rate and by years with small amounts of wood being developed. Some trees in the old forest may be found growing on fallen trunks whose ages can also be obtained. The combined ages of the fallen and living timber may record over a thousand years of the past.

Inside the trimline trees become established as the ice withdraws. Those growing just within are usually the oldest. Cores taken from these give the approximate time since the ice waned from their positions. The building of recessional moraines can also be dated by coring the appropriate trees in a similar way. There is, however, a period of unknown duration between the date of ice withdrawal from a particular place and the establishment of the earliest trees that have survived to the present. When the age of the oldest tree has been determined, this time must be added in order to have a true date of ice recession. Usually, this period cannot be figured. In the event old dated photographs are available which show an earlier position of the glacier, and the age of the oldest tree now growing at the same place is known, this interval can easily be calculated. Since earlier photographs had been made of the glaciers of this study, it was possible to determine this time as being between 10 and 17 years.

The radiocarbon age determination (Libby 1952) applied to wood material, buried during glacier advance and later exposed following recession, is effective in dating interstadial or interfluctuational forest remains. Through the use of radiocarbon dating and the botanical methods just outlined, it may be possible eventually to compare glacial and postglacial events throughout the world during the last 30,000 years. The development of scintillation counting of natural radiocarbon may extend the age limit to as much as 44,000 years (Arnold 1954).

An additional technique was applied along with those previously stated. Peat sections were collected from muskegs for the purpose of studying pollen stratigraphy. Muskegs, the name of Indian origin, are low, poorly-drained areas usually consisting of sedge and moss peat with some wood material and covering large tracts in Canada and Alaska. Pollen contributed mainly by the trees in the region is preserved in

muskegs with the dead plant materials that collect each year following the growing season. If the muskeg is known to rest on glaciated terrain, the peat and pollen that have accumulated should be continuous for all or much of postglacial time. Changes in the proportion of pollen from level to level in the sections sampled essentially depict the alteration of postglacial climate, since the plants growing at a particular place are primarily under the influence of climate. Moreover, climate influences glacier activity, and the data derived from such pollen study may help substantiate some of the findings of the other methods. Four peat sections were taken which are undergoing investigation.

The vegetation setting of the study region is the Rocky Mountain conifer forest. Engelmann spruce (*Picea engelmanni* (Parry) Engelm.) and alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) are the major constituents while lodgepole pine (*Pinus contorta* Dougl.) dominates areas which have recently been subjected to fire. White spruce (*Picea glauca* var. *albertiana* (S. Brown) Rehder) and several other conifers occur less frequently. On the western slopes such as in the Robson and Yoho areas, elements of the Pacific coast forest penetrate. Timber line is generally between 7500 and 8000 feet (ft.) or 2273-2424 meters (m).

Spruces are the commonest coniferous trees scattered on the outwash. Mountain avens (*Dryas drummondii* Rich.) is usually the most frequent plant to invade subsequent to ice recession, and on some moraines, such as those at Columbia and Southeast Lyell Glaciers, this species forms an almost continuous cover. The plumed fruits are easily dispersed through the air, especially during stormy periods in summer, and this feature undoubtedly explains the omnipresence of this plant on outwash.

Results

Robson Glacier. This glacier drains the northern slope of Mount Robson (12,972 ft.; 3931 m.), the highest summit in the Canadian Rockies. As the northwesternmost locality from which data were gathered, Robson Glacier is historically most complete by comparison to the others. A radiocarbon date for wood overridden *in situ* and later exhumed, about 1400 ft. (424 m) from the terminal moraine, has been determined to be 450 ± 150 years old (Dr. J. L. Kulp, Lamont Geological Observatory, New York, personal communication). This information implies that the glacier was advancing at this point between 1354 and 1654. From the oldest trees now growing on the terminal moraine, the date of recession following the attainment of maximal proportions is approximately 1783. During recession, six prominent moraines were built. The vegetation on these represents a classic illustration of plant succession and development following deglaciation. The approximate ages of these moraines from the oldest to the youngest are: 1801, 1864, 1891, 1907, 1910, and 1931. The minimum time which elapsed between ice withdrawal and the successful establishment of trees at Robson Glacier is 12 to 14 years. Between 1783 and 1908, the rate of recession was 7 ft. per year (2.1 m); between 1908 and 1953, the rate was 53 ft. per year (16 m). Recession from the terminal moraine has been 3338 ft. (1012 m).

Yoho Glacier. Ice receded about 1855 from the terminal moraine. Before this date, the glacier had not been further forward for at least four and a half centuries. Three recessional moraines were dated in the lower reaches of the outwash at 1863, 1878, and 1892. A factor of 10 to 12 years is added to the age of the trees, since from dated earlier positions of the ice and the ages of the oldest trees growing at the same places, this period passed before trees became established and survived. The recession rate from 1855 to 1901 is figured at 23 ft. per year (7 m); between 1901 and 1953 the rate was not calculated, although it must have been higher as the ice has receded a much greater distance than between the terminal moraine and the 1901 position.

Angel Glacier. This is a small hanging ice mass which is avalanche-fed from Mount Edith Cavell (11033 ft.; 3343 m). Formerly, the glacier was much more expanded. Recession was slow just following the maximum in about 1733 but has been more rapid in recent time. Three recessional moraines or moraine systems were dated as follows: 1793, 1871, and 1901. A period of 10 years was the minimum time required before trees began to develop. Ice had not been beyond the terminal moraine for at least the last three and a half centuries.

Columbia Glacier. Forming the headwaters of the Athabaska River and flowing from the vicinity of Mount Columbia (12294 ft.; 3725 m), Columbia Glacier has

receded 4695 ft. (1423 m) from its outermost advance position dated at 1724. No terminal moraine nor remnant of such is evident in the outwash. Where the lateral moraines reach the valley floor, termination is abrupt; the end moraine has probably been washed out. Because of this situation, the age of the oldest tree on the north lateral moraine just above the outwash was used to date the earliest recession of the glacier. The oldest tree on the south lateral moraine also directly above the outwash was somewhat younger. Ice receded earliest from the north side, about 40 years earlier than did ice on the south side. A lateral tongue of ice from a trunk valley formerly joined Columbia Glacier on the south, and it was essentially this that began to waste at a later date. Recession in the long period between 1724 and 1924 was only approximately 1300 ft. (394 m) while in the relatively short time, 1924 to 1953, it was 3395 ft. (1095 m.).

Dome Glacier. Dome and Athabaska Glaciers were united during their maxima. Dome reached its outermost stand and began to recede about 1875, much later than the earliest recession of its neighbor. Four recessional moraines were noted, but only the third from the terminal could be dated. Its formation was around 1880. Formation of the other moraines was in rapid succession following 1875. Recession has slowed down more recently; between 1875 and 1919, Dome Glacier receded 1750 ft. (530 m) while from 1919 to 1953, only 1050 ft. (318 m). This glacier receded less than Athabaska Glacier during the last three decades. The variation is probably affected by the insulating moraine covering its surface.

Athabaska Glacier. A section from an ice-pushed tree along the northwestern trimline above the former confluence of Dome and Athabaska Glaciers shows the date of tilting to be 1723. Ice withdrawal here was about 1744 while farther down-glacier recession began earlier in about 1731. The glacier receded slowly at first and even pushed forward to form a recessional moraine shortly within its outermost position. This moraine is dated approximately 1856. Recession between 1731 and 1922 amounted to 900 ft. (273 m.); between 1922 and 1953 it measured 2700 ft. (818 m.). Ice has not penetrated beyond the eighteenth century maximum for at least the last three and a half centuries.

Unnamed Glacier at the Head of Hilda Creek. This small glacier has its source in a cirque on the east side of Mt. Athabaska, (11452 ft.; 3470 m). Recession from the terminus occurred during the late eighteenth century around 1790; dwindling from the north lateral moraine up-glacier was about 1864. No measurement of recession was made.

Saskatchewan Glacier. No terminal moraine could be noted with assurance at this locality. Much of the outwash is devoid of plants, although a recessional moraine a short distance behind the presumed position of the terminal supports a few trees. Since the terminal moraine had apparently been flushed out by glacio-fluvial action, the trees just below the north trimline were sampled in order to date the earliest recession. This time was about 1854, and the recessional moraine noted above was formed at the close of the nineteenth or at the beginning of the twentieth century. Trees in the forest bordering the glacier to the north are over 250 years old. During the last five years recession has been extremely rapid, amounting to about 900 ft. (273 m) or an average of 180 ft. per year (55 m). The total recession has been approximately 4500 ft. (1364 m).

Southeast Lyell Glacier. Ice plowed into old forest in 1840 and the earliest retreat was almost simultaneous, about 1841. Mons Glacier, now a hanging ice tongue, was formerly coalesced as recently as 1902. The highest retreat rate of all the glaciers of this study was figured at Southeast Lyell Glacier. Between 1841 and 1926, retreat was 1320 ft. (400 m) or 16 ft. per year (4.8 m); between 1926 and 1953, 4125 ft. (1250 m) or 153 ft. per year (46.4 m). A rate of 168 ft. per year (51 m) was calculated for the period 1930 to 1953.

Freshfield Glacier. Recession began from the terminal area about 1869, although this date may be erroneous. The oldest tree growing below the lower northwest trimline indicates that ice withdrew much earlier, about 1851. This latter date seems more probable. Trees in the terminal area became established on a stream-cut bank. Since meltwater had been eroding the bank, trees could only begin growing when erosion ceased and stabilization occurred. For this reason 1851 is more likely the correct retreat date. Avalanches in places have disturbed the vegetation picture. Recession is 1050 ft. (318 m) between the terminal extent and the 1902 position and 4325 ft. (1311 m) between 1902 and 1953.

Peyto Glacier. No earlier extension of this glacier has taken place beyond the trimline for at least 300 years. The most recent maximum occurred about 1713,

and a readvance to almost this position produced a recessional moraine dated about 1865. Four additional moraines were dated as follows: 1878, 1894, 1897, and 1910. Total recession is approximately 3330 ft. (1009 m).

Bow Glacier. Deglaciation in 1673 was earliest at Bow Glacier of all the glaciers of this study. Trees beyond the recent trimline have been growing for almost six and a half centuries; ice has therefore not been further advanced for at least an equivalent time. Four moraines were built during retreat in 1850 and 1895 with two around 1898. No survey of recession was made. The glacier is now perched atop a cliff over which it formerly flowed.

Conclusions

These data show that the glaciers studied in the Canadian Rockies reached their maxima during the eighteenth and nineteenth centuries, with the exception of Bow Glacier whose maximum was attained during the seventeenth century. In many instances, the nineteenth century advances were comparable in amount or almost so with those in the centuries previous.

General agreement is seen with the work of Lawrence (1948) on Mount Hood in the Oregon Cascades, of Mathews (1951) in the British Columbia Coast Mountains, and of Cooper (1937) and Lawrence (1950*b*) in southeastern Alaska. All the glaciers here reported for the Canadian Rockies have been receding since the late nineteenth century or before, except for certain minor fluctuations in the more recent period. They thus appear to bear little or no relationship to several coastal Alaskan glaciers which made marked advances or are yet advancing during this century. Field (personal communication; Baird 1951) states that six of these have been advancing steadily for at least the last half century. At Prince William Sound, Alaska, for example, some glaciers have been further advanced during the twentieth century than during five centuries previous (Cooper 1942).

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