VARIATIONS OF BLUE, HOH, AND WHITE GLACIERS DURING RECENT CENTURIES*

Calvin J. Heusser†

GLACIERS in the Olympic Mountains of western Washington, as elsewhere in North America, enlarged in late-postglacial time and attained positions from which they have receded conspicuously. Former locations of the ice are marked by moraines and overridden surfaces which the regional vegetation is slowly invading. An examination of aerial photographs[1] of glaciers on Mt. Olympus taken in 1939 and 1952 clearly reveals the progress of recession. In 1952 Blue and Hoh glaciers (Fig. 1) appear rather inactive whereas a photograph of Blue Glacier taken about the turn of the century (Fig. 2) shows an actively discharging tongue, well in advance of its position in the early 1950's.

About 1900 glacier termini were nevertheless well behind positions reached when the ice stood farther down the valleys in past centuries. No written accounts or measurements are available from this pre-1900 period, although the ages of trees growing on moraines and outwash offer the means for fixing positions of the glaciers during the time before the earliest observations. The minimum periods elapsed since glaciers may have been even farther advanced are established by the ages of the oldest trees in the forests beyond the recent outermost limits of the ice.

A reconnaissance of Blue and Hoh glaciers and the vicinity of White Glacier was made during the 1955 summer, and the former limits of the ice were determined and dated. The purpose was to record the variations of Mt. Olympus glaciers so that the climate of this region during the last several centuries might be interpreted from these changes and compared with other localities where similar studies have been made. The relationship between glacier and climate changes has been demonstrated in such areas as the North Atlantic (Ahlmann, 1953) and an attempt has been made to relate glacier variations and sun spots in southeastern Alaska (Lawrence, 1950a).

This work was made possible through contract with the Office of Naval Research, Department of the Navy, and a grant by the Arctic Institute of North America and carried out in co-operation with the Olympic National Park Service. This assistance is gratefully acknowledged and also that

† Research Associate, American Geographical Society of New York.

[1] U. S. Geological Survey photographs for 1939 are GS-J8-75 and 76 and GS-J9-29; those for 1952 are GS-WR4-112 and 113.

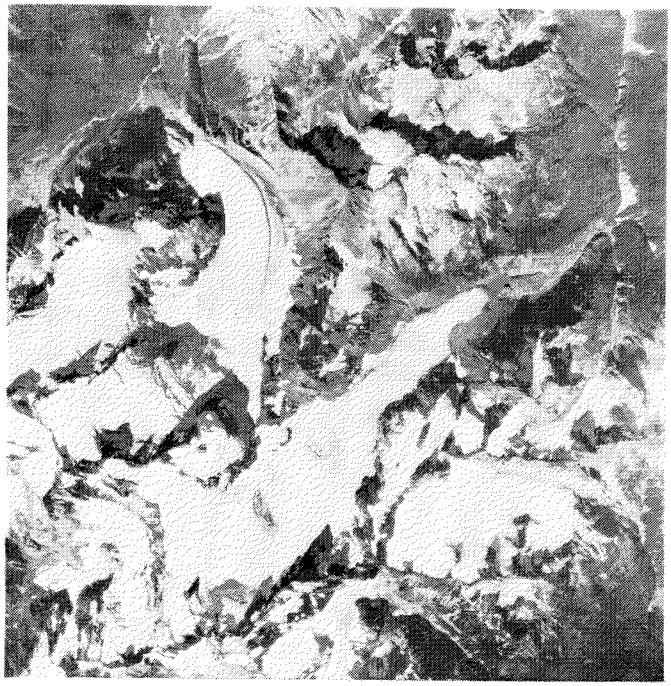

Photo: U.S. Geological Survey photograph GS-WR4-112.

Fig. 1. Aerial view of the Mt. Olympus massif showing Blue Glacier (upper left) and Hoh Glacier (middle right); White Glacier is to the left of the Blue but is not included in the photograph. October 3, 1952.

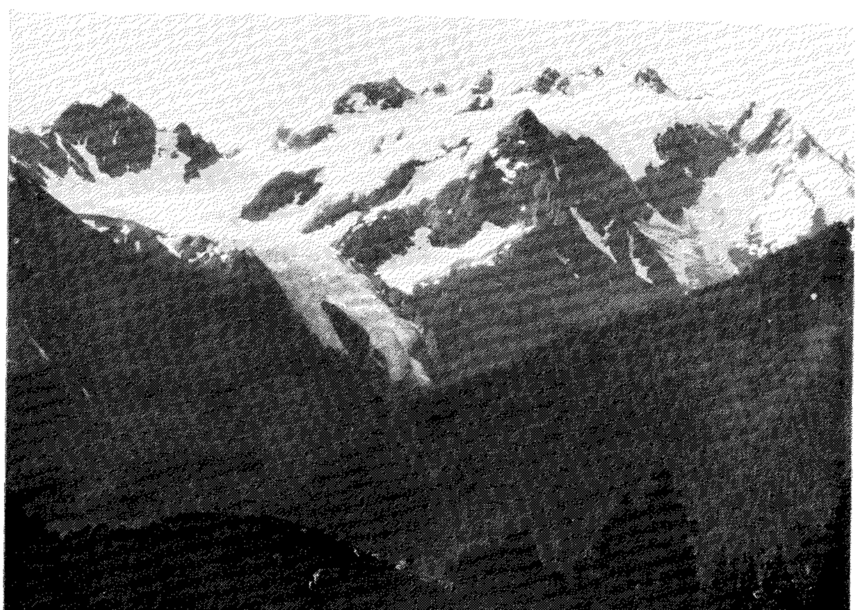

Photo: Courtesy Gunnar O. Fagerlund.

Fig. 2. Historic photograph of Blue Glacier taken about 1900 from the northwest. Mt. Olympus (7,954 feet elevation) is the highest point seen on the skyline.

given by Michael W. Hane, Richard C. Hubley, and Edward R. LaChapelle, field associates, and Gunnar O. Fagerlund and Hugh H. Bozarth of Olympic National Park.

The Blue, Hoh, and White glaciers

These glaciers descend the slopes of the Mt. Olympus complex, whose highest point is 7,954 feet above sea level, and their névé areas reach almost to this elevation (Fig. 3). The Blue curves northwestward to a terminus at approximately 4,000 feet while the Hoh flows northeastward to an elevation of about 3,600 feet (Fig. 4). White Glacier is north-northeast flowing and reaches to 4,000 feet. Hoh Glacier has a length of drainage of 3.3 miles, Blue Glacier of 2 miles, and White Glacier also of about 2 miles. The Hoh and the White flow down even gradients whereas the Blue is beset with a group of ice falls, several hundred feet in height, below the "Snow Dome" and the upper snow field of Mt. Olympus. Blizzard Pass at 6,100 feet connects the

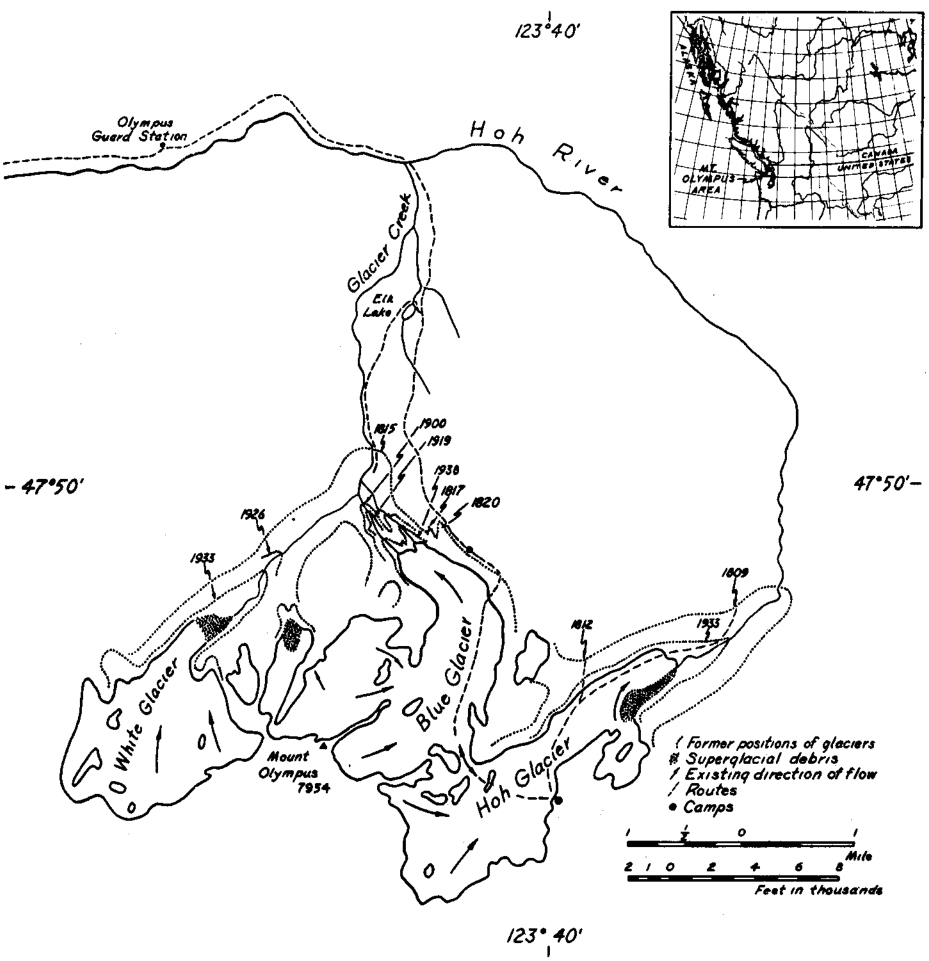

Fig. 3. Sketch map of Blue, Hoh, and White glaciers as of 1952.

Blue and the Hoh. All glaciers are geophysically temperate according to the Ahlmann (1948) classification and have firn limits at or near 5,500 feet.

Blue Glacier exhibits a diversity of features. Several medial moraines and two or three series of arch bands appear on the glacier surface. More than 100 feet above the northeast margin of the ice, at an elevation of 5,000 feet, is a sequence of lateral moraines that lower down descend into the timber. At least four of different ages occur, two of which are shown in Figure 5. Blue Glacier terminus rests above a steep slope more than a thousand feet above the valley floor. A bouldery ground moraine in the valley bottom at 2,650 feet elevation and a mile distant from the terminus marks the recent maximal extent of the glacier.

The exposed ice of Hoh Glacier is relatively clean and little broken by crevasses. A thin ablation moraine covers the tip of the snout and an inconspicuous lateral moraine blankets a small portion of the ice along the northwest edge. No distinctive recessional moraines have formed in the outwash. At the time of the last maximum, moraines were built into the forests along the valley sides and are now hundreds of feet above the glacier surface and outwash. The lowermost limit that the glacier reached at 2,900 feet elevation during the last few centuries was not visited, but it can be seen on the aerial photographs that no terminal moraine exists. It probably has been reworked by streams issuing from the terminus on account of the narrowness of the Hoh Valley.

Fig. 4. View of Hoh Glacier terminus. August 16, 1955.

Fig. 5. Moraines at 5,000 feet elevation above the northeast margin of Blue Glacier. The inner of the two weathered moraines is in the middle of the photograph and the early nineteenth century moraine, comparatively unweathered, is at the left.

The conspicuous mud flow on the southeast side of the Hoh snout (Figs. 1 and 4) is indicative of the physiographic instability of this region. The 1939 aerial photographs do not show this feature, but those from 1952 do. This suggests a disturbance that occurred some time during the 1940's or the early part of the 1950's and possibly was a result of earthquakes. White Glacier also exhibits a heavy mantle of detritus that clearly represents dynamic dumping. This earth slide has spread across the tongue above the terminal area and is shown in the 1939 aerial photographs (see GS-J8-76, also the 1944 photograph in Danner, 1955, page 39). It may be the result of an earthquake prior to the dislodgement of earth in the vicinity of the Hoh. An early photograph of White Glacier taken from across the valley in 1926 does not show this superglacial cover but what appears to be an earlier slide or morainal material (*The Mountaineer*, 1926, frontispiece). Danner (1955) states that strong earthquakes occurred in the Puget Sound area in 1939, 1946, and 1949.

Hoh Glacier is the major source of Hoh River which flows generally westward across the Olympic Peninsula and reaches the Pacific Ocean just north of Ruby Beach. Glacier Creek, a major tributary, carries the discharge of Blue and White glaciers. In the upper reaches, the Hoh River and its branches flow mainly in deep valleys, which are steep-sided, whereas the lower course is relatively broad with gravel bars and flats. Blue Glacier can be reached by trail from the Hoh Ranger Station via Olympus Guard Station. Hoh Glacier is readily accessible by way of Blizzard Pass. Most of these places are shown in Figure 3 and on the U. S. Geological Survey map, Mount Olympus Quadrangle, 1935, Scale 1:62,500.

Glacier variations

Botanical and geological evidence, old ground photographs, aerial photographs, and Park Service records were used to determine the positions of the ice margins during the times of maxima and up to the middle of the 1950's.

Trees growing on moraines and outwash provided most of the dates for recession. If a time interval that equals the period before trees invade the denuded terrain is added to the age of the oldest tree on a particular surface, the date of withdrawal may be fixed more accurately. Twelve years were added to the ages of trees growing on the down-valley moraines, whereas a somewhat longer interval was added in the cases of trees on moraines at higher elevations. Tree ages were obtained from cores taken with a Swedish (Djos) increment borer from the base of each trunk. Lawrence (1950b) has described the methods.

Two ancient moraines border the northeast edge of Blue Glacier at 5,000 feet elevation. Their ages are unknown although the oldest trees indicate that they are at least pre-1250 in age. The outer one of the pair, by virtue of its position, is older, but it is without trees, less extensive, and smaller in size. The younger and larger one is partly tree covered and is composed of both fine and coarse debris with angular boulders that have been subjected to prolonged weathering (Fig. 5).

The earliest datable advance of Blue Glacier took place about 1650. This date is based on the ages of an alpine fir and mountain hemlock that are growing on a morainal remnant and that were tilted by a subsequent advance in the early nineteenth century. The locality where these trees are standing is about 200 feet lower in elevation than the previously mentioned ancient moraines. Downed and rotting timber occurs on the slope and the dated trees are beside a large scarred mountain hemlock over 500 years in age. The 1650 advance extended just beyond that of the nineteenth century at this location, but elsewhere evidence of the 1650 ice thrust appears to have been buried or obliterated. Trees of the ancient forest beyond this moraine are over seven centuries old and accordingly preclude further extension of the glacier for an equivalent period.

When the Blue was at its maximum, the northeast margin of the glacier above the ice fall spilled over through two narrow defiles forming two bifurcated lateral tongues. The ice at this time curved along the ancient moraines and descended several hundred feet, dumping large quantities of boulders and glacio-fluvial material through the forests below. The ages of young trees that have invaded as these tongues receded disclose that stability of the lateral moraines was achieved in the early nineteenth century. The western tongue withdrew about 1817 and the eastern tongue receded about 1820.

This time, as might be expected, is somewhat later than that of the recession of the lower valley snout. Recession from this recognizable outermost and lowermost position of Blue Glacier occurred about 1815, while White Glacier presumably had coalesced with the Blue and the two formed a common front. The 1952 aerial photograph GS-WR4-112 (Fig. 1) clearly shows the former boundary of the glaciers. The small tops of the young even-aged trees that became established when the glaciers receded contrast distinctly with the fuller crowns of the old trees growing beyond the former extent of the ice. Although no recessional moraines are evident in the valley below the ice fall, four are present up-glacier above the 1820 moraine near the northeast margin of the glacier; two appear to have been formed during the nineteenth century while the third was formed about 1900 and the last during the second decade of this century.

Recession of Blue Glacier between 1815 and 1900 is estimated at approximately 2,800 feet. Between 1900 and 1919 the terminus receded about 300 feet and further retreat until 1938 has amounted to about 1,500 feet. These measurements are based in part on the transfer of positions of the ice margin taken from early photographs of about 1900 (Fig. 2) and of about 1919 to the U. S. Geological Survey map entitled "Mount Olympus Quadrangle." The 1919 photograph is the property of the Committee on Glaciers of the American Geophysical Union and is on file at the American Geographical Society. As discussed by Matthes (1946, page 221) the Park Service has periodically measured the change of position of the terminus since 1938. Retreat amounted to somewhat more than 800 feet between 1938 and 1953 and an advance of 10 feet was measured in 1955. Photographs of the terminus in 1953 and 1955 (Figs. 6a and b) reveal a thickening of the snout.

Dates for the maximum of Hoh Glacier are quite similar to those for the Blue. Along the north lateral moraine, above and below the terminus, recession occurred respectively in 1812 and 1809. The lowermost point that the glacier reached in recent centuries was not visited, but it is likely that recession there was somewhat earlier than 1809. No evidence to indicate earlier advances of this glacier was located. The glacier had not exceeded its nineteenth century maximum for over 450 years. It is estimated that the terminus withdrew approximately 3,500 feet between the early 1800's and 1933; additional retreat from 1933 to 1952 has been about 3,000 feet.

Although the White Glacier was not visited except the terminal moraine, some estimates of recession are presented in so far as reliable data will allow. Retreat of the terminus between the early 1800's and 1926 has amounted to approximately 6,500 feet, between 1926 and 1933 to about 1,000 feet, and between 1933 and 1952 to 3,000 to 4,000 feet. The superglacial cover on the snout obscures the position of the ice margin so that only an approximate measurement can be given. Total recession is between 10,500 and 11,500 feet and thus is much greater than that for the Blue (4,900 feet) or the Hoh (6,500 feet). During withdrawal, the terminus advanced at least twice as indicated by certain discontinuities in the vegetation pattern on

Photo: Gunnar O. Fagerlund.

Fig. 6b. Blue Glacier terminus, from the same position at which the 1953 photograph was taken. Note the thickening of the snout as indicated by increased blocking from view of the distant summit. September, 1955.

the early 1940's this trend has reversed sharply. Variations of the glaciers studied are generally in accord with these trends, and Blue Glacier behaviour, better known than that of the Hoh or the White, agrees more closely. On the basis of the relationship shown between the glacier variations and the climatic fluctuations for this century, the important advances of about 1650 and the early 1800's would appear to be coincident with climatic conditions favouring glacier growth, that is, higher precipitation and lower temperature.

The situation in the Mt. Olympus area is not local. Longley (1954) has shown that temperatures in western Canada have been rising since the relatively cold 1880's, although since about the mid-1940's they have fallen similarly to those from Tatoosh Island. Temperate glaciers elsewhere in the Cordillera of northwestern North America have, in general, followed this trend during this period and prior to this time have behaved, with some exceptions, like those in the Olympics. In this discussion the variations of Blue Glacier will be representative of the study area for purposes of comparison with variations of other North American glaciers.

The two undated pre-1250 moraines of the Blue appear to be related to those that Harrison (1956a) has reported as corresponding to an older age than our present glaciers but younger than those dating from Wisconsin glaciation. In more recent studies in the Malaspina Glacier district, Alaska,

Photo: Gunnar O. Fagerlund.

Fig. 6a. Blue Glacier terminus. September, 1953.

the outwash. The first readvance probably occurred during the 1800's and the second during the early part of the present century.

Discussion

Certain conclusions can be drawn from the foregoing data on the variations of Mt. Olympus glaciers. Since the early nineteenth century variations of the three glaciers studied appear to have been synchronous, it is likely that behaviour before and after was also synchronous. The three glaciers studied have their source areas in similar environments and all drain essentially northward. Of course, some disparity induced by local factors must be expected. Earth slides covering portions of the Hoh and White snouts exemplify an influence that may affect the rate of recession. Nevertheless, such a factor should cause only a small discrepancy in the general synchronism. Other glaciers on Mt. Olympus, notably the Hubert, the University, and the Humes, on the other hand, may have been somewhat out of phase with those studied, since their source areas are at lower elevations and their aspects are not northerly.

Hubley (1956) has analyzed the recent climate trends based on meteorological records taken on Tatoosh Island, just off the northwestern Olympic Peninsula. His graphs show relatively high precipitation and low temperatures about the turn of the century while afterward and up until the early 1940's precipitation has been low and temperatures have been rising. Since

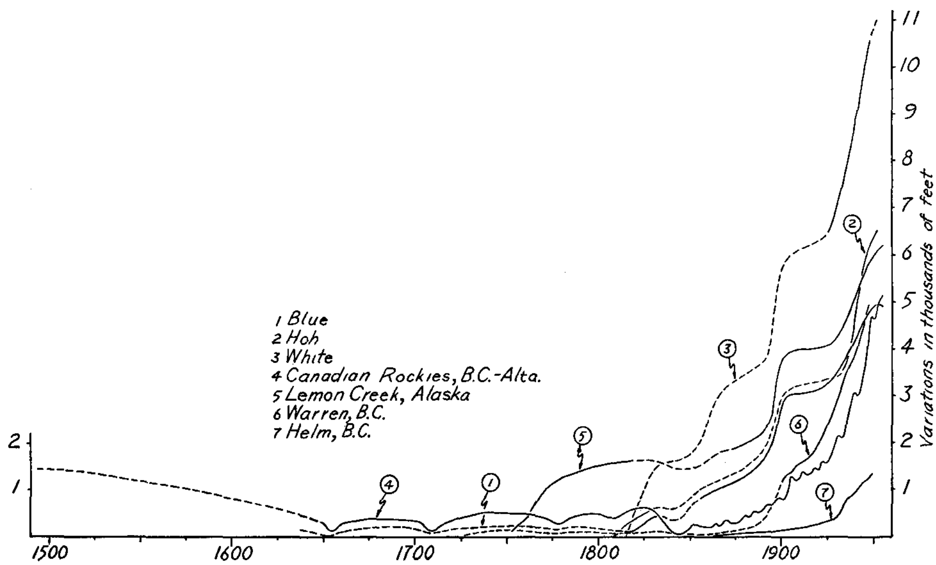

Fig. 7. Diagram representing time-distance variations for Blue, Hoh, and White glaciers and compared with those from representative glaciers elsewhere in northwestern North America. Data for the Canadian Rockies are from Heusser (1956), for Lemon Creek Glacier from Heusser (1955), and for Warren and Helm glaciers from Matthews (1951).

Plafker and Miller (1957) have been able to date an advance that seems to correlate with either or both of the ancient Blue Glacier moraines. This advance culminated between 600 and 920 A.D. in Icy Bay and between 970 and 1290 A.D. in Yakutat Bay and was followed by recession that began before 1400 and ended about 1700.

Regional glacier variations during the last few centuries are shown in Figure 7. For comparison, representative glaciers were chosen from the Canadian Rockies, Alberta-British Columbia (Heusser, 1956); the Juneau Ice Field in southeastern Alaska, Lemon Creek Glacier (Heusser, 1955); and from Garibaldi Park in southwestern British Columbia, Warren and Helm glaciers (Mathews, 1951).

The curve for the Canadian Rockies (Fig. 7) is the most detailed and extensive one, dating back to about 1500. It shows that the earliest recognizable variation in this region occurred during the mid-1600's. Blue Glacier advance during this century appears to have been contemporaneous. The second variation in the curve for the Canadian Rockies occurred during the early 1700's. Blue Glacier presumably readvanced or its rate of retreat decreased, although no evidence from which to infer its behaviour at this time is available. Warren Glacier began retreating about 1725 and Lemon Creek Glacier about 1750. It would seem that glaciers generally had been affected by the favourable conditions for glacier growth during the early 1700's. Variations are evident during the late 1700's and early 1800's and following the last, glaciers in the Olympics began to retreat with only minor halts and surges up until the 1950's.

In the Canadian Rockies and in Garibaldi Park, the second quarter of the 1800's was apparently an interval of greater glacier activity than in any comparable period in the preceding two centuries. Lemon Creek Glacier receded a relatively small amount at this time and may have readvanced slightly. In the Olympics recession was presumably slow. Since about 1850, recession for the glaciers under discussion has been generally continuous and with rates increasing in the late 1800's (Blue, Lemon Creek, and Warren) or in the early 1900's (Canadian Rockies).

The first and second decades of this century represent an interim of relatively slow retreat with some moraine formation. Evidence for this is found in all areas diagrammed in Figure 7. After 1925-30 glaciers melted back at a most rapid rate; White Glacier shows this very strikingly and more so than any of the others under consideration. The measurements by the Olympic National Park Service of Blue Glacier terminus show a particularly high retreat for the period 1939 to 1944 with subsequent smaller amounts, except for 1950-51. During the late 1940's recession was slow but between 1954 and 1955, as previously mentioned, a small advance was observed accompanied by terminal thickening (Figs. 6 a and b). Hubley (1956) has reported on this latest advance as well as others observed during 1955 in the northern Cascade Mountains of northwestern Washington and on Mt. Shasta in California. Also in this regard, Bengtson (1956) has noted the changes in the advancing front of Coleman Glacier on Mt. Baker in the Cascades, and West (1955) has written of the thickening tongue of Commander Glacier in the Purcell Mountains of British Columbia between 1947 and 1954.

The recently published curve of variations for Nisqually Glacier, Mt. Rainier (Harrison, 1956b, page 683) is in general accord with the trends represented in Figure 7. An advance of this glacier is figured during the mid-1800's, retreat is rapid in the late 1800's, readvance and moraine formation follow in the first decade of this century, and subsequent recession has been most pronounced. No advance has been registered during the 1950's, although a "wave" of ice is progressing down-glacier and has been observed since 1944. Additional data for comparison are provided by several other investigators. Cooper (1937) dated the earliest retreat of ice in Glacier Bay, Alaska as 1760. Lawrence (1950a, 1953) placed the earliest recession of the Juneau Ice Field glaciers between 1700 and 1775 and indicated a readvance during the mid-1800's. According to Lawrence (1948) in about 1740 glaciers on Mt. Hood, Oregon stood farthest advanced in recent centuries and during subsequent retreat readvanced about 1840.

As the nineteenth century advance, as well as the advances in the seventeenth and eighteenth centuries, has been greater in one area than in another, so the glacier activity in the twentieth century has varied at different places. Columbia Glacier in Prince William Sound, Alaska, for example, was at the maximum for the last 500 years between 1914 and 1922 (Field, 1937; Cooper, 1942), and Norris Glacier, flowing from the Juneau Ice Field, had not been further advanced in 1910 than for nearly 500 years (Muntz, 1955). Such noteworthy advances are known from only a few localities whereas at other places they have been found to occur as small fluctuations. It seems evident that the conditions favouring such glacier advance can be widespread, although they may be accentuated locally.

References

Ahlmann, H. W. 1948. Glaciological research on the North Atlantic coasts. Roy. Geog. Soc. Res. Series No. 1, 83 pp.

——————1953. Glacier variations and climatic fluctuations. New York: Am. Geog. Soc., 51 pp.

Bengtson, K. E. 1956. Activity of the Coleman Glacier, Mt. Baker, Washington, U. S. A., 1949-1955. J. Glaciol. 2: 708-713.

Cooper, W. S. 1937. The problem of Glacier Bay, Alaska: a study of glacier variations. Geog. Rev. 27: 37-62.

——————1942. Vegetation of the Prince William Sound region, Alaska, with a brief excursion into past-Pleistocene climatic history. Ecol. Monogr. 12: 1-22.

Danner, W. R. 1955. Geology of Olympic National Park. Seattle, 68 pp.

Field, W. O. 1937. Observations on Alaskan coastal glaciers in 1935. Geog. Rev. 27: 63-81.

Harrison, A. E. 1956a. Multiple glaciation since the Ice Age. Science 124: 181-182.

——————1956b. Fluctuations of the Nisqually Glacier, Mount Rainier, Washington, since 1750. J. Glaciol. 2: 675-683.

Heusser, C. J. 1955. Preliminary study of the historic fluctuations of Lemon Creek Glacier terminus. *In* Prog. Rpt. Juneau Ice Field Research Proj., Alaska 1954. Am. Geog. Soc., pp. 34-41. (mimeo.).

——————1956. Postglacial environments in the Canadian Rocky Mountains. Ecol. Monogr. 26: 263-302.

Hubley, R. C. 1956. Glaciers of the Washington Cascade and Olympic Mountains; their present activity and its relation to local climatic trends. J. Glaciol. 2: 669-674.

Lawrence, D. B. 1948. Mt. Hood's latest eruption and glacier advances. Mazama 30: 22-29.

——————1950a. Glacier fluctuations for six centuries in Southeastern Alaska and its relation to solar activity. Geog. Rev. 40: 191-223.

——————1950b. Estimating dates of recent glacier advances and recession rates by studying tree growth layers. Trans. Am. Geophys. Un. 31: 243-248.

——————1953. Recession of the past two centuries. *In* Periodicity of deglaciation in North America since the late-Wisconsin maximum. Geog. Ann. 35: 83-94.

Longley, R. W. 1954. Temperature trends in Canada. Proc. Toronto Meteor. Conf. 1953: 207-211.

Mathews, W. H. 1951. Historic and prehistoric fluctuations of alpine glaciers in the Mount Garibaldi map-area. J. Geol. 59: 357-380.

Matthes, F. E. 1946. Report of the committee on glaciers, 1945. Trans. Am. Geophys. Un. 27: 219-233.

The Mountaineer. 1926. Olympic Peninsula. The Mountaineer 19.

Muntz, A. P. 1955. Recent glacier activity in the Taku Inlet area, Southeastern Alaska. Arctic 8: 83-95.

Plafker, G. and D. J. Miller. 1957. Glacial features and surficial deposits of the Malaspina district, Alaska. U.S. Geological Survey open file rpt., 13 pp.

West, R. 1955. The recent history of the Commander Glacier. Can. Alp. J. 38: 99-101.