

## GLACIAL ACTIVITY IN THE WESTERN UNITED STATES

COMMENTS ON PROFESSOR A. E. HARRISON'S PAPER\* (*Journal of Glaciology*,  
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PROFESSOR HARRISON'S paper emphasizes the fact that the pronounced rate of recession and shrinkage of glaciers in the western United States observed during the 1920's and 1930's has shown a marked decrease during the past decade and in some cases a terminal advance and an increase in thickness has been observed. Specific data on the Nisqually Glacier on Mt. Rainier, Washington, and on the Sperry and Grinnell Glaciers in Glacier National Park, Montana, confirm this. The writer has been directly connected with observations on the Nisqually Glacier since 1940 and on the Sperry and Grinnell Glaciers since 1944.

The summary by Professor Harrison indicating growth or shrinkage for various years is overly simplified since a single descriptive term is apparently not applicable to the behavior of an entire glacier. This is particularly true in the case of a long, valley glacier extending through a considerable range in altitude. Such a glacier is subject to many changes and variations as a result of weather phenomena. Heavy winter precipitation over a period of years may increase the thickness in the upper reaches while the lower reaches may be thinning together with a recession of the terminus. Conversely, a glacier advancing at the terminus may be thinning in the upper reaches due to different combinations of weather conditions. Observations on the Nisqually Glacier clearly demonstrate that the upper part of the glacier can be thickening while the lower part is thinning and the terminus is receding. The results of cross-profile measurements on the Nisqually Glacier since 1941 are summarized in the table below. The four profiles are located, in ascending order, 0.8, 1.6, 2.2, and 2.7 km. from the terminus. The terminus in 1955 was 1.3 km. from the highway bridge over the Nisqually River.

NISQUALLY GLACIER, MT. RAINIER NATIONAL PARK, WASHINGTON

<i>Mean elevation of cross-profiles, in meters</i>				
<i>Year</i>	<i>Cross-profile No. 1</i>	<i>Cross-profile No. 2</i>	<i>Cross-profile No. 2A</i>	<i>Cross-profile No. 3</i>
1941	1604.2	1823.6	—	—
1942	1601.7	1820.2	—	2058.0
1943	1598.1	1817.2	—	2059.5
1944	1594.7	1813.0	—	2057.1
1945	—	1811.7	—	2059.2
1946	1590.4	1810.2	—	2062.0
1947	—	1808.7	—	2065.0
1948	1585.3	1808.1	1958.6	2070.2
1949	1584.4	1809.6	1967.2	2076.0
1950	1582.2	1814.2	—	—
1951	1580.7	1820.3	1975.1	2082.4
1952	1578.9	1825.8	1974.5	2076.9
1953	1577.3	1829.7	1973.6	2074.2
1954	1576.7	1833.1	1976.6	2076.6
1955	1579.8	1835.8	—	2075.7

\* Publication authorized by the Director, U.S. Geological Survey.

The foregoing table shows that a thickening in the upper part of the glacier was indicated by the 1945 measurements and that the thickening continued through 1951 as shown by the values for cross-profile No. 3. The overall increase from 1944 to 1951 was 25.3 m. Since 1951 there has been alternate thinning and thickening. The increase in thickness moved down the glacier and first became evident at cross-profile No. 2 in 1949. This thickening has continued through 1955 with an overall increase of 27.7 m. since 1948. The increasing thickness was noticeable to some extent at cross-profile No. 1 in 1954 but was not of sufficient magnitude to show an increase in the average elevation for the entire cross-profile. However, the thickening did become evident in 1955 when the measurements showed an increase of 3.1 m. since 1954.

There has been a recession of the terminus every year since 1918 when annual measurements were started by the National Park Service.

In view of the concurrent changes in growth and recession actually observed on the Nisqually Glacier it does not seem adequate to describe the annual changes as simply growth or shrinkage.

The conditions of growth shown in Professor Harrison's report for Glacier National Park for the years 1948 through 1951 is not consistent with observations that have been made by the National Park Service and the Geological Survey. The main part of the terminus of the Sperry Glacier, the largest in the Park, was mapped in 1945, 1947, 1949, 1950 and 1952. There was a continued recession throughout this seven-year period although the rate from 1950 to 1952 was somewhat less than the rate from 1945 to 1950. A profile was measured across the Sperry Glacier in 1949 and remeasured in 1950 and 1952. The 1950 results were essentially the same as in 1949. The 1952 mean elevation of the cross-profile was 1.7 m. higher than in 1950. This was due to two factors. First, the 1952 measurements were made on August 19 whereas the 1950 measurements were made on September 19. In the normal year there would be considerable ablation between August 19 and September 19. Second, the seasonal snowfall, July to June, for 1952 was the highest recorded at West Glacier in a record extending back to 1933. No measurements have been made on the Sperry Glacier since 1952.

Two profiles have been measured on the Grinnell Glacier starting in 1950, the results of which are summarized in the following table. These are what might be termed "radial profiles" as they originate at a common point a short distance in front of the glacier.

## GRINNELL GLACIER, GLACIER NATIONAL PARK, MONTANA

*Mean elevation of profiles, in meters*

Date	Profile No. 1			Profile No. 2		
	Station 30°5-152°4	Station 152°4-304°8	Station 304°8-457°2	Station 30°5-152°4	Station 152°4-304°8	Station 304°8-457°2
Sept. 14, 1950 .. ..	1970.1	1984.3	—	1969.0	1988.3	2001.0
Aug. 22, 1952 .. ..	1970.1	1984.2	1990.2	1969.1	1988.1	1999.1
Sept. 4, 1953 .. ..	1969.1	1982.9	1988.4	1968.5	1987.1	—
Sept. 27, 1954 .. ..	1969.3	1983.0	—	1968.9	1987.9	2000.8
Sept. 8, 1955 .. ..	1969.6	1982.8	1988.5	1969.2	1987.8	2000.7

Changes of a relatively minor nature are shown by the comparisons in the above table for the five-year period, 1950-55. These cannot be construed as indicating any particular trend but rather as indicating a state of balance or equilibrium.

The terminus of the Grinnell Glacier was mapped in 1945, 1947, 1950, 1951 and 1952. The period 1945 to 1950 showed some recession but the amount was small. In 1951 there was a slight advance of the terminus and in 1952 a slight recession to essentially the same position occupied in 1950. A few random observations in 1953, 1954 and 1955 indicate that no significant changes have occurred. The variations of the terminus within the ten-year period, 1945-55, were within such narrow limits that they cannot be considered as indicating either recession or advance but rather as verifying the state of equilibrium indicated by the cross-profile measurements.

It is of noteworthy interest that during the decade, 1945 to 1955, there was a pronounced thickening of the Nisqually Glacier whereas the Sperry and Grinnell Glaciers have more nearly maintained a condition of balance. This verifies Professor Harrison's statement that parallelism in behavior of the glaciers in different parts of the country does not necessarily exist.

### FURTHER NOTE ON THE NISQUALLY GLACIER, MOUNT RAINIER, WASHINGTON

By A. E. HARRISON

SOME questions have been raised regarding the interpretation of the paper by V. R. Bender and A. L. Haines entitled "Forty-two years of recession of the Nisqually Glacier on Mount Rainier" in *Erdkunde*, Bd. 9, Ht. 4, 1955, p. 275-81, with relation to the paper by the present writer on "Fluctuation of the Nisqually Glacier, Mt. Rainier, Washington, since 1750" in the *Journal of Glaciology*, Vol. 2, No. 19, 1956, p. 675-83. Actually the two papers are in agreement, but it may be worth while to point out some of the implications of the fluctuations and add some estimates of their effect on the data published by Bender and Haines.

Mention is made by Hofmann (*Erdkunde*, Bd. 9, Ht. 4, 1955, p. 281-86) of the increased thickness observed on the Nisqually Glacier during the last decade. This increase was detected by Arthur Johnson of the United States Geological Survey after 1945, and an estimate of the volume involved can be obtained from the cross-profile measurements included in Johnson's progress reports on file at the United States Geological Survey in Washington, D.C.

An area of approximately 1 km.<sup>2</sup> is included in the region covered by the cross-profiles, and the increase in volume over this area between 1945 and 1950 was about 12,000,000 m.<sup>3</sup>. The area above the profiles includes about 4.8 km.<sup>2</sup>. The accumulation at the highest levels is probably less, and some of the accumulation has moved downward to produce the growth in the profile region, so it is logical to assume a proportionately smaller increase of volume at the higher levels. This increase has been estimated as 24,000,000 m.<sup>3</sup>. Deducting an estimated shrinkage of 1,000,000 m.<sup>3</sup> in the area of stagnant ice below the profiles gives a net growth of 35,000,000 m.<sup>3</sup> for the Nisqually Glacier during the five-year period between 1945 and 1950. This estimate is probably low.

Shrinkage returned temporarily in 1951 and 1952. The year 1952 was particularly destructive. A loss of 15,000,000 m.<sup>3</sup> has been estimated for the two years from the appearance of landmarks in photographs made in these years. This loss in volume leaves a net growth of 20,000,000 m.<sup>3</sup> between 1945 and 1952.

Consideration of these estimated data changes the story of the recession of the Nisqually Glacier somewhat. The total loss is greater and the period of the shrinkage is shorter. Actually, the period of shrinkage is even less than thirty-five years. The Nisqually Glacier did not shrink appreciably in volume until after 1920. This conclusion is based on an inspection of old photo-