

GLACIAL ACTIVITY IN THE WESTERN UNITED STATES

By A. E. HARRISON

(Department of Electrical Engineering, University of Washington, Seattle)

ABSTRACT. Four coordinated reports on recent trends in glacial activity in the State of Washington, U.S.A., have been prepared by three authors and three of these appear in this issue of the *Journal of Glaciology*. The fourth report will appear in a later number. Other reports regarding the condition of glaciers in this state and in other regions of the western United States have appeared in various mountaineering journals. It is the purpose of this paper to serve as a reference to the bibliography in this field and show how the detailed story included in the companion papers is part of a widespread change in trend. Results reported by other observers are reviewed briefly. In addition, some data on observations by the author in the Sierra Nevada are included in order to compare the magnitude of the activity in California and Washington.

ZUSAMMENFASSUNG. Vier zusammenführende Berichte über die jüngste Richtung der Gletschertätigkeit im Staate Washington der Vereinigten Staaten von Amerika sind von drei verschiedenen Autoren vorbereitet worden und drei von diesen Berichten erscheinen in dieser Ausgabe des *Journal of Glaciology*. Der vierte Bericht wird später in dieser Zeitschrift auch veröffentlicht werden. Weitere Berichte in Bezug auf den Zustand der Gletscher sowohl in diesem Staat als auch in anderen Regionen im Westen der Vereinigten Staaten sind in verschiedenen Fachzeitschriften erschienen. Der Zweck dieses Artikels ist als Referenz zur Bibliographie auf diesem Gebiet zu dienen und zu zeigen, wie die in den begleitenden Artikeln inbegriffene Einzelheiten wiedergegebene Geschichte einen Teil eines weitgehenden Wandels der Zustände ausmacht. Resultate, die von andern Beobachtern berichtet wurden, werden kurz besprochen. Ausserdem sind einige Data über Beobachtungen des Verfassers in der Sierra Nevada mitinbegriffen, um das Tätigkeitsmass in Kalifornien mit dem in Washington zu vergleichen.

RECENT reports of growth of glaciers in four different areas of the United States have focused attention on the possibility that the catastrophic recession of past decades may be ended or at least temporarily suspended. The new trend was first noted in 1946 on the Nisqually Glacier on Mt. Rainier, Washington, by Arthur Johnson¹ in unpublished progress reports to the United States Geological Survey. Johnson's measurements indicated that the ice thickness at an elevation of 2100 m. had been increasing since 1944, although the level of the glacier surface at lower elevations was continuing to decrease. Weldon Heald² reported the possibility that the Palisade Glacier in the Sierra Nevada, California, was increasing in thickness in 1946. Evidence of increased ice on the Lyell Glacier in the Sierra Nevada was observed by the author in 1949^{3, 4} and led to an intensified interest in glacial activity in this country when the significance of the coincidence in the time of the glacial growth on Mt. Rainier and Mt. Lyell was recognized.

Increased glacial activity has also been reported in the Wind River Range of Wyoming and from Glacier National Park, Montana (see Fig. 1, p. 667). Meier⁵ observed that glaciers in the Gannet-Fremont Peak area in the Wind River Range were increasing in thickness at their higher elevations, although the lower margins were continuing to shrink. Dightman and Beatty⁶ reported similar results in Glacier National Park and attributed the change to a colder, wetter climate in Montana during the last few years.

Spectacular growth of the Coleman Glacier on Mt. Baker, Washington, has been measured by Kermit Bengtson^{7, 8}. This glacier was the first one in the United States definitely known to be advancing at its terminus. The results of Bengtson's surveys will shortly be published⁹ and the detailed reports by Hubley¹⁰ and the author¹¹ on the condition of the glaciers in the State of Washington appear in this issue of the *Journal of Glaciology*. Similar activity in other glaciated areas in the mountains of Washington has been suspected, but very little quantitative information on the changes in other glaciers has been available.

A program of coordinated measurement of meteorological factors and glacial activity in the Olympic Mountains and the Cascade Range in Washington has been initiated by Richard Hubley. His observations confirmed the idea that the growth of glaciers was general and not limited to a few isolated examples. These observations also suggest that the new trend is most pronounced in the northern Cascade Range.

In addition to the qualitative observations of recent growth on the Nisqually Glacier on Mt. Rainier in the last article in this series, the author has presented a history of earlier fluctuations of

this glacier so that the comparison of glacial activity in this country with other regions of the world may be extended to a longer period of time. The Nisqually Glacier is particularly suitable for this purpose because its popularity and accessibility have provided many photographs which help to establish the dates of moraines and reinforce the conclusions based on tree ring counts. For this reason, the data on the Nisqually Glacier may be useful in checking the idea of synchronism in glacial behavior in different regions of the world.

Continued shrinkage of the lower margins of the glaciers in California and Oregon, and even on Mt. Rainier¹¹, has led to some skepticism regarding the conclusion that glacial activity has increased in the southern Cascade Range or in the Sierra Nevada. While the activity is undoubtedly greatest in the State of Washington, the same trend has been reported on Mt. Shasta, a 4300 meter volcanic peak near the southern limit of the Cascade Range in California. A photograph taken in 1955 by R. H. Watkins¹² shows unmistakable evidence of increased ice thickness since 1933 on the Konwakiton Glacier, with a new, bulging tongue of active ice invading a region of stagnant ice.

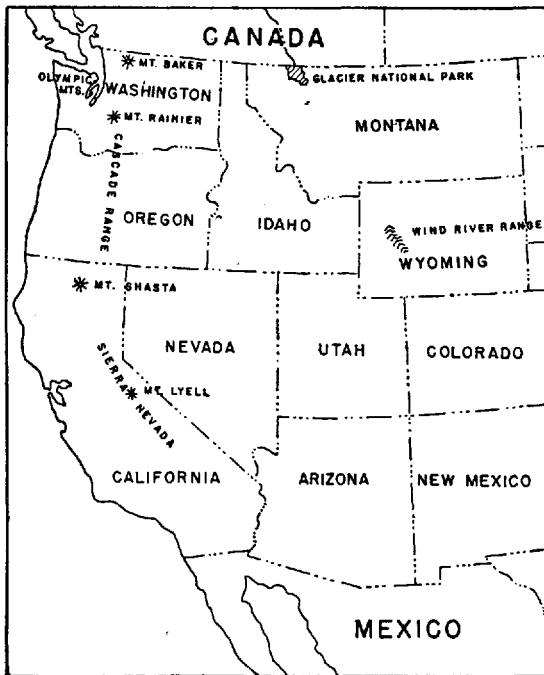


Fig. 1. Sketch map showing the various centres of activity in the western United States

The same trend is indicated by increased ice thickness at the higher areas of the Lyell Glacier in the Sierra Nevada, California, since 1937. This change can be recognized by comparing the two photographs of Mt. Lyell in Figs. 2 and 3, p. 677. The rock shoulder, circled in the 1937 photograph, projected from the ridge separating the two halves of the Lyell Glacier and extended about 8 m. above the ice surface at that time but is completely covered in the 1953 photograph. Both photographs were made near the end of the ablation season and no new snow had fallen. Although the thickness of the firn at this point was not measured in either year, the condition of the firn surface in 1953 left little doubt that a uniform increase in thickness sufficient to cover the rock had occurred. This conclusion is substantiated by photographs which were taken by other observers during the intervening years.

It is difficult to tell from these photographs whether the loss of ice at the lower portion of the Lyell Glacier, indicated by larger areas of rock near the moraine, is compensated by the increased accumulation of other areas. However, the change in volume of the Lyell Glacier has been small

since 1937, in contrast with the period between 1919 and 1931 when approximately half of the volume of the Lyell Glacier disappeared.

Although there are indications that the glaciers of the different regions of the United States have reacted similarly if conditions are averaged over a number of years, parallelism in behavior does not always exist. Quantitative data are not available, but qualitative observations obtained from photographs have been used in preparing the comparison of the different regions in the United States in the table below.

Year	Mt. Lyell, California	Nisqually, Washington	Mt. Baker, Washington	Glacier National Park, Montana
1932	Growth	Growth		
1933	Balance			
1934	Shrinkage			
1936	Shrinkage (?)	Balance		
1938	Growth	Shrinkage		
1939	Shrinkage	Shrinkage		
1940	Shrinkage	Shrinkage		
1941	Best Growth	Shrinkage		
1942	Balance	Shrinkage		
1944		Shrinkage		
1946	Growth (?)	Growth		
1947		Growth		
1948		Growth		Growth
1949	Slight Shrinkage	Growth		Growth
1950		Growth	Growth	Growth
1951	Slight Shrinkage	Shrinkage		Growth
1952	Growth	Severe Shrinkage	Shrinkage	Shrinkage
1953	Balance	Growth	Growth	
1954	Shrinkage	Best Growth	Best Growth	
1955	Shrinkage	Growth	Growth	

These conflicting observations do not alter the general conclusion that a trend toward glacial growth is evident in this country. It will be difficult to evaluate the relative intensity of the present activity in comparison with earlier periods of growth. The earlier advances inherited considerable ice from previous maxima, while the glaciers must now refill canyons which are either empty or contain only thin relics of stagnant ice. A much greater intensity or duration will be indicated if the final position even approaches the location of earlier advances.

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Fig. 2. (See p. 667.) Mt. Lyell and Lyell Glacier on 5 September 1937. The rock shoulder marked by the circle extended about 8 m. above surface of the ice. Thin ice still covers the area behind the terminal moraine



Fig. 3. Mt. Lyell and Lyell Glacier on 29 August 1953. The rock shoulder is covered completely, indicating an increased thickness at this point of 8 m. Bare rock is exposed behind the moraine